PB85-117109

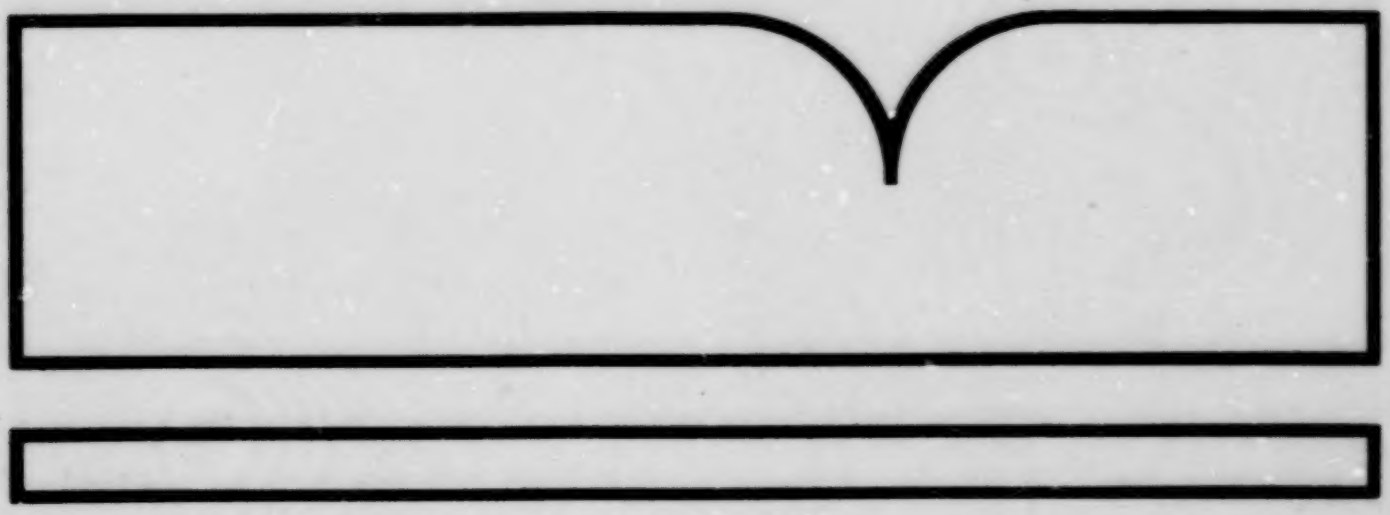
Evaluation of Processed Municipal Wastes in Landfill Cells

Systech Corp., Xenia, OH

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Nov 84



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Nov 84

by J. M. Kemper, N. J. Kleinhenz, and J. T. Swartzbaugh.

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The U.S. Environmental Protection Agency (EPA) engaged Systems Technology Corporation (SYSTECH) to compare the leachates and gases produced by municipal solid wastes (MSW) that were processed in various ways prior to landfilling. Beginning in January 1975, five tests cells (buried landfill simulators) were monitored until August 1980. These five test cells contained municipal refuse in the following conditions: (1) shredded and baled, (2) baled, (3) baled and saturated with water, (4) shredded, and (5) nonprocessed. Leachate and gas samples were collected to determine moisture balances, leachate pollutant concentrations, and gas compositions in order to evaluate the processing methods. The baled wastes were found to produce large quantities of dilute leachate, while the shredded waste produced smaller quantities of more concentrated leachate, compared to nonprocessed waste.

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16. ABSTRACT

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The baled wastes were found to produce large quantities of dilute leachate, while the shredded waste produced smaller quantities of more concentrated leachate, compared to nonprocessed waste. Leachate from waste that was both baled and saturated with water was similar to the nonprocessed waste in leachate volume and concentration. Gas composition data from the wastes were inconclusive due to numerous gas leaks and the small volume of gas produced in the system. Recommendations are included to alleviate this problem for future landfill simulations.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and governmental concern about the nation's environment and its effect on the health and welfare of the American people. The complexity of the environment and the interplay among its components require a concentrated and integrated attack upon environment problems.

The first step in seeking environmental solutions is research and development to define the problem, measure its impact, and project possible remedies. Research and development is carried out continually by both industry and governmental agencies concerned with improving the environment. Much key research and development is handled by EPA's Municipal Environmental Research Laboratory. The Laboratory develops new and improved technology and systems, to prevent, treat, and manage wastewater and community sources; to preserve and treat public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research -- a vital communications link, between the research and the user community.

This document provides information about the effects on leachate and gas production resulting from shredding or baling of municipal solid waste prior to its placement in landfill simulators.

The intended audience for this document includes those involved in the design of, as well as the development of, operation plans for sanitary landfills for municipal solid waste.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

ABSTRACT

The U.S. Environmental Protection Agency (EPA) engaged Systems Technology Corporation (SYSTECH) to compare the leachates and gases produced by municipal solid wastes (MSW) that were processed in various ways prior to landfilling. Beginning in January 1975, five tests cells (buried landfill simulators) were monitored until August 1980. These five test cells contained municipal refuse in the following conditions: (1) shredded and baled, (2) baled, (3) baled and saturated with water, (4) shredded, and (5) nonprocessed. Leachate and gas samples were collected to determine moisture balances, leachate pollutant concentrations, and gas compositions in order to evaluate the processing methods.

The baled wastes were found to produce large quantities of dilute leachate, while the shredded waste produced smaller quantities of more concentrated leachate, compared to nonprocessed waste. Leachate from waste that was both baled and saturated with water was similar to the nonprocessed waste in leachate volume and concentration. Gas composition data from the wastes were inconclusive due to numerous gas leaks and the small volume of gas produced in the system. Recommendations are included to alleviate this problem for future landfill simulations.

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SECTION 1

INTRODUCTION

The intent of the project was to demonstrate the effect of preprocessing landfilled wastes upon the amount of leachate produced and the concentrations of the impurities in those leachates. It was anticipated that shredding would enhance the concentrations by increasing the exposed surface areas of the waste. It was also anticipated that baling wastes would increase the amount of leachate by reducing the interstitial spaces to hold water and that the concentration would be reduced by restricting both the exposed area and the exposure time. The combined effect of shredding and baling was a point of conjecture because the shredding should increase surface areas, but the baling should exclude access of the water to those surfaces. In order to best determine the effect of each of these preprocessing treatments and the combination of these effects, a protocol was established which would permit the measured control of water in and a measure of leachate out.

The cells were established and filled to provide data for municipal solid waste (MSW) as received, baled, shredded, and shredded then baled. One cell was established with baled MSW and was maintained with a high liquid level. This was to provide data regarding the exposure time of the water to the refuse in the bales. With no forced circulation inside the cell, the concentration of the impurities may become very high inside the bales, while the moisture passing through the cell externally to the bales would remain relatively low in concentrations. The cells were constructed and early work was performed under Contract 68-03-2024 which was awarded in June 1974. Test cells were constructed and then waste was emplaced in them during the time period of November and December 1974. Leachate and gas monitoring took place until August 1980. Finally, the waste was removed from the test cells at the beginning of July 1981. Thus, the entire duration of both Contracts 68-03-2024 and 68-03-2598 was 84 months. The waste was in place for a total of 79 months. Monitoring of leachate production and gas and leachate analyses under strict control of a water addition regimen took place over a period of 5 1/2 years.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The moisture data collected in the study to date indicate that the baling of refuse prior to landfilling exerts a positive effect both on the time frame to reach apparent field capacity (initiation of continuous leaching) and the volume of leachate produced over the time period covered by this report. Baled refuse does apparently absorb water as demonstrated by the fact that the normalized moisture-retained values obtained in this study slowly increased with time. This same phenomenon also occurred in the nonbaled cells, thus, indicating a gradual reaching of theoretical field capacity. There are no major differences in moisture retention noted in the baled cells regardless of whether the baled waste was shredded or nonshredded. As far as moisture retention is concerned, baling is the process which should be considered, not whether the waste is initially shredded. In the case of the nonbaled cells, the moisture-retained values were much higher than the baled refuse for both shredded and nonshredded waste. Also, the nonprocessed waste had approximately 20 percent more moisture retained than did the shredded waste.

Some significant conclusions arise from the results of the leachate data analysis. Based on the statistical analysis of the data collected over the period covered by this report (over 5 1/2 years), the nonbaled, shredded waste (Cell No. 4) was the only waste which consistently exhibited no correlation in leachate concentration values with the other four cells. This is not unexpected as the shredded material does present a larger total surface area exposed to infiltration and decomposition forces. The other four cells containing the baled, shredded waste; the baled, nonshredded waste; the saturated baled, nonshredded waste; and the nonpreprocessed waste showed no such significant differences during the time period covered by this report.

The analysis of the gas composition data collected during the period of time covered by this report indicates that the methane production in a real world landfill situation is dependent on the variable aerobic/anaerobic systems of bacterial decomposition. Dominance of each system of bacteria at any given time is in turn dependent to a great degree on the amount of dissolved oxygen in the infiltering water.

In regard to the effects of preprocessing on gas composition, it would appear that while all observed methane production was cyclic in nature, the maximum values reached during the high points of the respective cycle for each cell were different and could possibly be attributed to the preprocessing of the waste. This could not be verified through a comparison with nonpreprocessed waste as no methane has been observed in Cell 5 (see

Table B-1 in Appendix B). In-house work and literature data with digesters lead us to the conclusion that this cell may have "soured" irrevocably as evidenced by its continually lower pH compared with the other four cells. In this situation, the methane-forming bacteria, which are very susceptible to low pH as well as oxygen, had no chance to become well established.

Water saturation of a landfill could create a situation where higher concentrations of methane are produced. This conclusion is supported by the analysis of the composition data from Cells 2 and 3 which both contained baled whole waste. Cell 3 was saturated and produced methane concentrations approximately half again as great as Cell 2.

The temperature data collected indicated that internal landfill temperatures will vary with the seasons and the external ambient air temperature. The internal landfill temperatures in the lower portions of the fill will lag behind the ambient air temperature changes. This means that the internal lower portion of the landfill will be slightly warmer (than ambient) in winter and cooler in summer. The overall temperature variations are also much more stable than the ambient air temperatures.

The temperature comparison between the cells in this study indicated no major differences in the monthly average temperature after an initial stabilization period of about 3 months. Based on this finding, it was concluded that temperature difference was not a major factor to be considered in evaluating preprocessing steps such as those considered in this study.

Information obtained during the study gives rise to a number of recommendations for further research efforts as well as for facility modifications which should be incorporated into future study plans. Future research efforts should be made with the primary purpose of obtaining accurate gas volume measurements of those gaseous components produced by the landfilling of preprocessed wastes. Such studies should be conducted utilizing relatively inexpensive, bench-scale type operations which can be replicated. This type of an experiment would permit a better statistical population for data analysis than the large test cells utilized in the program presented herein. Such smaller-scale studies would also be able to incorporate gas-tight design configurations which are not readily achieved in large-scale test cells.

The primary problem in gas volume studies is leakage. It is recommended that test cells for such a study be contructed of steel, with metal gas collection lines, and the entire unit sealed with welded seams. This could be much more readiliy accomplished with scaled-down studies than with large-scale test cells.

SECTION 3

EXPERIMENTAL PROCEDURES

TECHNICAL DISCUSSION OF TESTING PROTOCOL

Objective

Reliable data on leachate and gas production from landfilled MSW under controlled conditions is of continuing utility to the waste management community as bases for both design guidance and operational guidance. The decomposition of MSW in a landfill environment results in the production of gases and leachates. Research has been performed regarding the concentration of gases in and around landfills and regarding the dispersion of gases into and through the soils. Little research, however, has been directed toward defining the production rate, the quantity, and the quality of the gas generated as well as the leachate.

The specific objective of this contract was to determine the gas production rate (quantitatively and qualitatively) of MSW in a simulated landfill environment. A second objective was to simultaneously monitor the quality and quantity of leachates produced during this research. Ultimately, the data on gas and leachate generation should be used in models for predicting landfill gas migration and leachate production. It should be understood, however, that such modeling was not a part of this effort.

Discussion of Physical Data Parameters

The design of the test cell is schematically represented in Figure 1. With this test set-up it was possible to measure the requested parameters of temperature and moisture. With the gas meter arrangement, we believed it to be possible to monitor the volume of gas generated in the cell as well as the gas that had migrated through the soil cover into the freeboard. In addition, the volume of leachate generated was monitored.

Discussion of Chemical Parameters

Throughout the experiment, samples of the gas and leachate formed were to be collected and analyzed. The gas was analyzed by gas chromatographic techniques to determine the presence of CO_2, CH_4, O_2, and N_2.

The leachate was analyzed for pH, chemical oxygen demand (COD), total organic carbon (TOC), total solids (TS), total kjeldahl nitrogen (TKN), total alkalinity, iron, copper, zinc, cadmium, chromium, lead, and nickel. All of these parameters are indicative of the quality, or pollution potential of leachate.

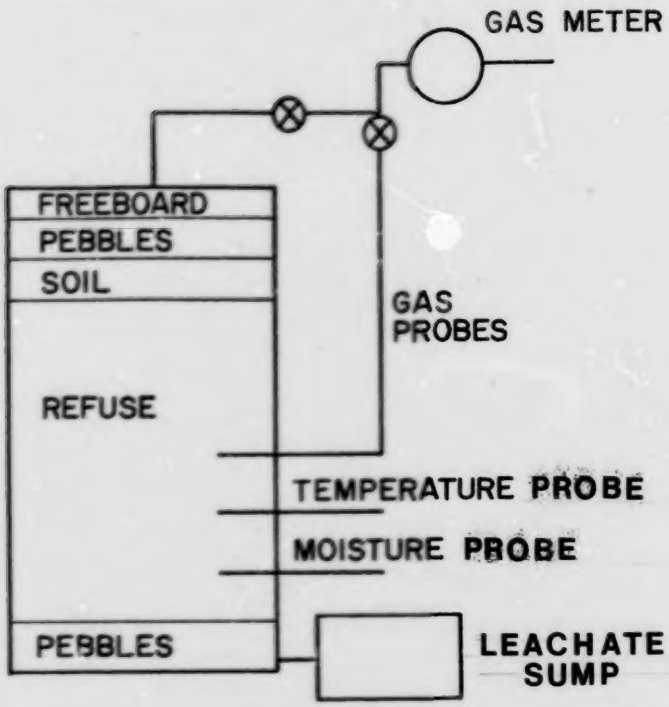

Figure 1. Stylized diagram of test cell.

Sources of Waste, Method of Shredding and Baling, and Characterization

This research required the simulation of the five different landfill conditions represented in Table 1. This table shows that four of the five tests required that the waste receive some form of processing (shredding or baling) before it was placed in the test cells.

TABLE 1. LANDFILL CONDITIONS

Cell number	Form of refuse		Condition in cell		Drainage simulation	
	Raw	Shredded	Compacted	Baled	Drained	Saturated
1		X		X	X	
2	X			X	X	
3	X			X		X
4		X	X		X	
5	X		X		X	

Samples of the solid waste loaded into each of the test cells were to be sorted in order to ascertain their compositions. A categorization of the municipal waste is necessary in order to draw meaningful conclusions about the waste composition and decomposition products. The waste material was to be separated into ten categories as follows:

1. Food waste
2. Garden waste
3. Paper
4. Plastics, leather, rubber
5. Textiles
6. Wood
7. Metals
8. Glass
9. Ash, rocks, dirt
10. Fines (less than 2.5 cm [1 in.])

FACILITY DESIGN AND CONSTRUCTION PHASE

This section discusses the design of the test facility and the subsequent efforts involved in the actual construction of the test cells and the instrumentation room.

Facility Design

The basic design requirement was to provide a test facility which would allow for the continuous monitoring of the quantity and quality of gas and leachate production in five different test cells. Each of the cells was to

contain MSW which had been preprocessed in a different manner. To satisfy this requirement, five identical in-ground test cells were designed. The cell arrangement is illustrated in the facility layout shown in Figure 2. This arrangement provided for reasonable accessibility without apparent instrumentation difficulties and without allowing temperature influence between cells. The test facility was designed for instrumentation allowing the monitoring of temperature, moisture, and gas generation within the cell as well as for gas and leachate collection lines.

Temperature monitoring instrumentation consisted of a total of 120 copper-constantan thermocouples, with each cell having 24 thermocopules distributed at various points throughout the refuse. The thermocouple extension leads for each cell were connected via a polyvinylchloride (PVC) conduit to a separate 24-position selection switch located in a central instrumentation cell. The output of each of these five selector switches is connected to another selector switch whose positions correspond to the five test cells. The output of this switch is connected to a digital readout temperature indicator.

The moisture monitoring instrumentation was designed to utilize both gypsum soil blocks and porous cup tensiometers. Gypsum soil blocks operate on the principle that the moisture in the soil is absorbed by a gypsum block which separates two electrodes. Any change in soil moisture causes the resistance between these electrodes to change. The change in resistance is measured on an ohmmeter calibrated to directly read moisture content. There were nine of these gypsum soil blocks spaced throughout each test cell at three levels in rows of three. The extension leads for these probes were connected, via the PVC conduit used for the thermocouples, to a switching unit similar to that described for the temperature monitoring system.

The porous cup tensiometer consists of an air-tight, water-filled tube connected to a porous ceramic-cup probe. The tendency of the water to flow in and out of the tube through the ceramic probe will depend upon the partial pressure of water outside the probe. A vacuum gauge connected to the ceramic tube allows measurement of the water remaining within the tube, and thus indirectly, of the moisture outside the tube.

The gas monitoring system design consisted of ten collection probes for each cell which connected to a manifold and valve arrangement inside the instrumentation cell and subsequently connected to a wet test gas meter. The actual gas collection piping inside the cells consisted of three rows of three perforated plastic pipes in the refuse and one such gas probe in the test cell freeboard area above the refuse. The manifold design permitted gas collection from any of the three levels, the freeboard area, or any combination of these two regions. Figure 3 schematically presents this piping and instrument arrangement. A vacuum pump was used to draw gas samples from the cells into glass sample bottles. The samples were then transported to the laboratory for gas chromatographic analyses. It is felt that the composition data thus obtained was reasonably reliable and that any leaks in the cells were not sufficient to allow contamination of a gas sample withdrawn in such a rapid fashion.

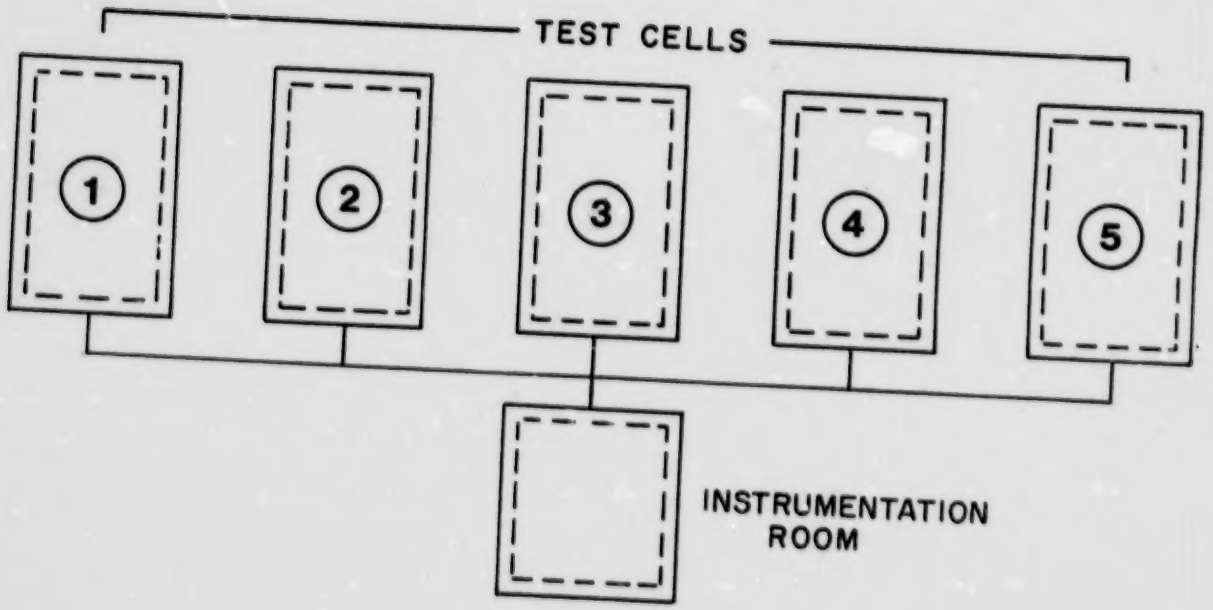

Figure 2. Test cell arrangement.

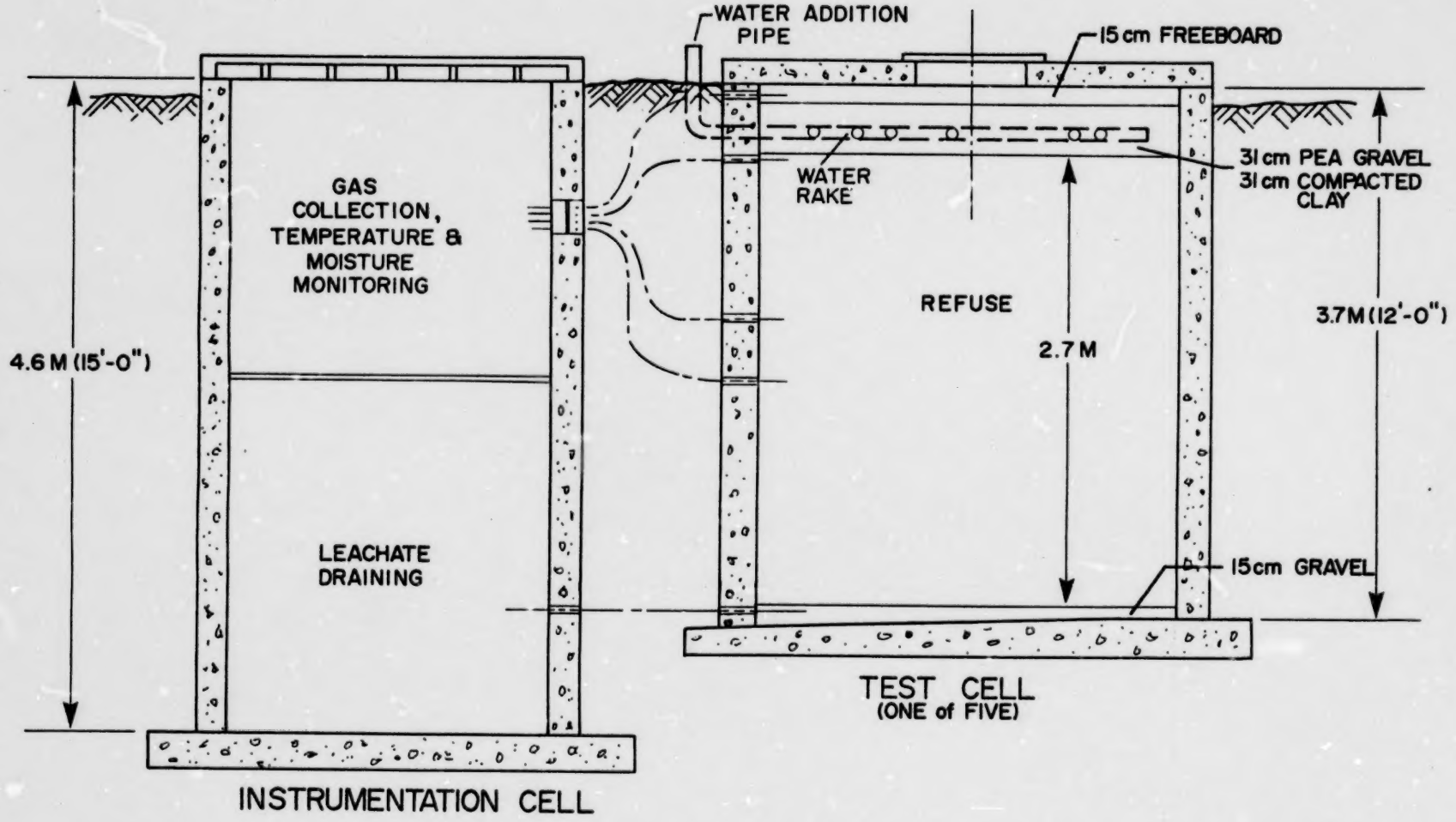

Figure 3. Facility layout.

Leachate collection was provided through drain lines leading from the center front of the sloped floor of each test cell into the instrumentation cell. These leachate collection lines were valved at the instrumentation cell to facilitate the periodic removal of leachate which collected in the bottom of the test cells. The volume of leachate drained could then be measured and samples taken for analyses.

The interior design of the test cells was intended to simulate a typical landfill situation while allowing for the required monitoring and sampling. The contents of a typical, fully charged cell (see Figure 3) consisted of a 15.2-cm (6-in.) base of nonreactive silica gravel and three layers of baled refuse, or approximately 2.7 meters (9 ft) of compacted refuse. This was covered with approximately 30.5 cm (12 in.) of clay compacted to a unit dry density of approximately 1442 kg/m^3 (90 lb/ft^3) with a 30.5-cm (12-in.) overlay of pea gravel. There were 15.2 cm (6 in.) of freeboard between the pea gravel and the top of the test cell. A water injection rake was buried in the pea gravel to provide a water source which distributed the water uniformly over the top interior surface of the cell.

The instrumentation and data collection cell was designed to allow all data collection to be handled in one central facility rather than several small facilities. This cell was located in front of the middle test cell and contained the terminals and collection ports for all the gas, leachate, temperature, and moisture monitoring equipment.

Facility Construction

Actual construction of the test facility was started in August 1974. The five tests cells were constructed of reinforced concrete with inside dimensions of 2.1 meters (7 ft) wide × 3.4 meters (11 ft) long × 3.7 meters (12 ft) high. The walls were 20 cm (8 in.) thick, and the cells were set in a straight line with a 1.1-meter (3.5-ft) clearance between adjacent cells. Instrumentation access was provided by casting sleeves into the cell and then installing bulkhead fittings.

The instrumentation and data collection cell, which was centrally located to the the test cells, was constructed to contain the terminals and collection ports for all the gas, leachate, temperature, and moisture measuring equipment. It was similarly constructed of reinforced concrete with inside dimensions of 2.4 meters (8.0 ft) × 2.4 meters (8.0 ft) × 4.6 meters (15 ft). Note that concrete was used for test cell construction rather than steel as originally proposed for several reasons: (1) substantially greater ease of construction, (2) a severe steel supply problem during the proposed construction time, and (3) prohibitive cost for required size of cells. This change from steel to concrete construction seemed reasonable at the time, but later difficulties in gas volume measurement indicated that steel would have been much better for the purposes of gas collection.

The construction sequences were completed reasonably close to schedule with the only major difficulty resulting from a higher than anticipated water

table. Although solving the groundwater problem did cause delays in construction, the potential for water migration into the instrumentation and test cells was such that the delays were justifiable.

To preclude the possibility of water migration, the following steps were taken during construction:

1. A PVC water stop was cast into the concrete at the interface of the floor and cell walls.

2. The exterior of the instrumentation and test cell walls were coated with an asphaltic compound.

3. Field tile was installed around the perimeter of the instrumentation and test cells, below floor level, to channel all groundwater and surface water to a sump area.

4. A sump and pump were installed to prevent the groundwater level from exceeding the height of the test cell floor.

Upon completion of the concrete construction, the next major effort was the preparation of the instrumentation cell for the installation of the monitoring equipment. This work consisted of installing the intermediate floor, the cell roof, and the instrument mounting panels and shelves. The next step was the installation of the electrical utilities including service outlets and lights. Concurrently, the general contractor started the backfilling operation. The gas and leachate transport tubes were installed during this time.

In the last phase of construction prior to cell charging, the thermocouple and moisture probe systems were prewired. This involved installing the selector switches inside the instrumentation cell and running the extension leads through a conduit to terminal boxes located adjacent to each test cell. When the prefabricated thermocouples and moisture probes were received from the supplier, they were installed through the test cell walls and connected to the extension leads in the prewired terminal boxes. The completion of this phase permitted the checkout of each probe prior to installation in the refuse. This installation system also allowed data recording to begin immediately after the probe was installed in the refuse.

The initial technique for sealing the thermocouple and moisture probe wires where they exit from the cell was accomplished using two different types of sealant: PVC cement and silicone rubber. The undersides of the test cell covers were coated to prevent any foreign material (that could be expected to form from the interaction of the concrete with moisture or other substances) from entering the leachate collection system and affecting the analyses and results. This coating was applied by lifting the covers approximately 16 to 20 meters (5 to 6 ft) off the ground with a crane and then applying a coat of tar epoxy with paint rollers.

In an attempt to ensure a seal between the cell cover and the walls of the test cells, 1.9-cm (3/4-in.) OD × .5-cm (1/8-in.) wall vinyl tubing was installed on the wall surface. This gasket material was attached to the top of the cell wall using plastic anchors. In addition, a silicone rubber adhesive was used to provide further sealing.

The device used to protect the barbed hose connectors consisted of a 3-meter (10-ft) long wood channel constructed of 2 × 4s and 1/2-in plywood. This unit was placed against the walls over the connectors for both cell charging and compaction and then removed for gas probe installation.

With the completion of the above procedures, the facility construction phase of the project was completed, and the cell charging phase could begin.

CELL CHARGING AND OPERATION

Cell Loading

The program protocol called for loading MSW into five different test cells. The following identified the type of solid waste placed in each of the five test cells.

Cell	Type of Pretreatment
1	Shredding and baling
2	Baling
3	Baling (saturated conditions)
4	Shredding
5	No pretreatment

The initial concept was to obtain all the solid waste utilized in the project from the City of Oakwood, Ohio, in order to help ensure waste uniformity. However, during the early phases of the project, the local baling facility was damaged by fire; and a search for a new baling facility was initiated. This search resulted in the baling operations being transferred to the Cobb County, Georgia, Baler Facility. A shredder facility was also located in nearby DeKalb County. Therefore, MSW for Cell 1 was obtained in DeKalb County. The MSW was first shredded and then transported to the Cobb County Baler Facility, baled, and subsequently transported to the test site in Franklin, Ohio. Due to the extremely complex logistics (including material, equipment, and personnel requirements) as well as the financial requirements which ensued, it became impracticable to obtain nonbaled MSW from this same source. The nonbaled MSW was instead obtained from the original source, Oakwood, Ohio.

An additional requirement of the contract called for the characterization of the solid waste at the different facilities. Therefore, provisions were made for handsorting the solid waste at each facility from which waste was obtained. Three of these sorts were performed for each facility in order to better categorize the solid waste used in this study (see Table 2). A comparison of the results of the waste categorization procedures is illustrated in Figure 4.

TABLE 2. AVERAGE REFUSE COMPOSITION (wt %) FOR ATLANTA AND OAKWOOD REFUSE

Categories	Atlanta (average of 3 sorts)	Oakwood (average of 3 sorts)	Overall (average of 6 sorts)
Food waste	7.6	6.9	7.3
Garden waste	7.9	1.2	4.6
Paper	50.7	51.2	51.0
Plastics, leather, rubber	4.5	7.4	6.0
Textiles	4.2	2.1	3.2
Wood	1.6	0.6	1.1
Metal	7.3	11.6	9.5
Glass	10.1	14.0	12.0
Ash, rocks, dirt	2.6	2.3	2.4
Fines	3.4	2.6	3.0
Moisture percent*	27.2	27.3	27.25

*Moisture content is calculated on an as-received or "wet weight" basis.

Cell 4 (shredded, nonbaled refuse) and Cell 5 (as-received refuse) were loaded first as this refuse was available locally form the City of Oakwood, Ohio. After completion of the loading of Cells 4 and 5, the remaining three cells were loaded with the baled solid waste from the Atlanta, Georgia, area. In the following sections, the loading of the test cells, located in Franklin, Ohio, is described.

Nonbaled Test Cells (Cells 4 and 5)

The loading of the nonbaled test cells began on November 25, 1974. Refuse from the City of Oakwood, Ohio, was delivered to the Montgomery County South Incinerator by the Oakwood collection vehicles. The waste material for Cell 4 was then sampled, and the necessary handsorts for waste chacterization were made. Once sampled, the waste was shredded and hauled to Franklin for loading. The procedure followed for Cell 5 was identical with the exception that the shredding step was omitted.

Baled Test (Cells 1, 2, and 3)

The loading of Cells 1, 2, and 3 presented more challenge than did Cells 4 and 5. The main reason was the complex coordination required between various personnel, municipalities, companies, and equipment manufacturers. The complexity of this coordination is illustrated by the fact that the refuse shredding facility was located geographically southeast of Atlanta, Georgia, while the Baler Facility was located in Marietta, Georgia, a city northwest of Atlanta. Provision had to be made for hauling the shredded refuse to the Baler Facility for baling. Additionally the bales were banded to ensure their delivery to Franklin in a baled configuration. A local

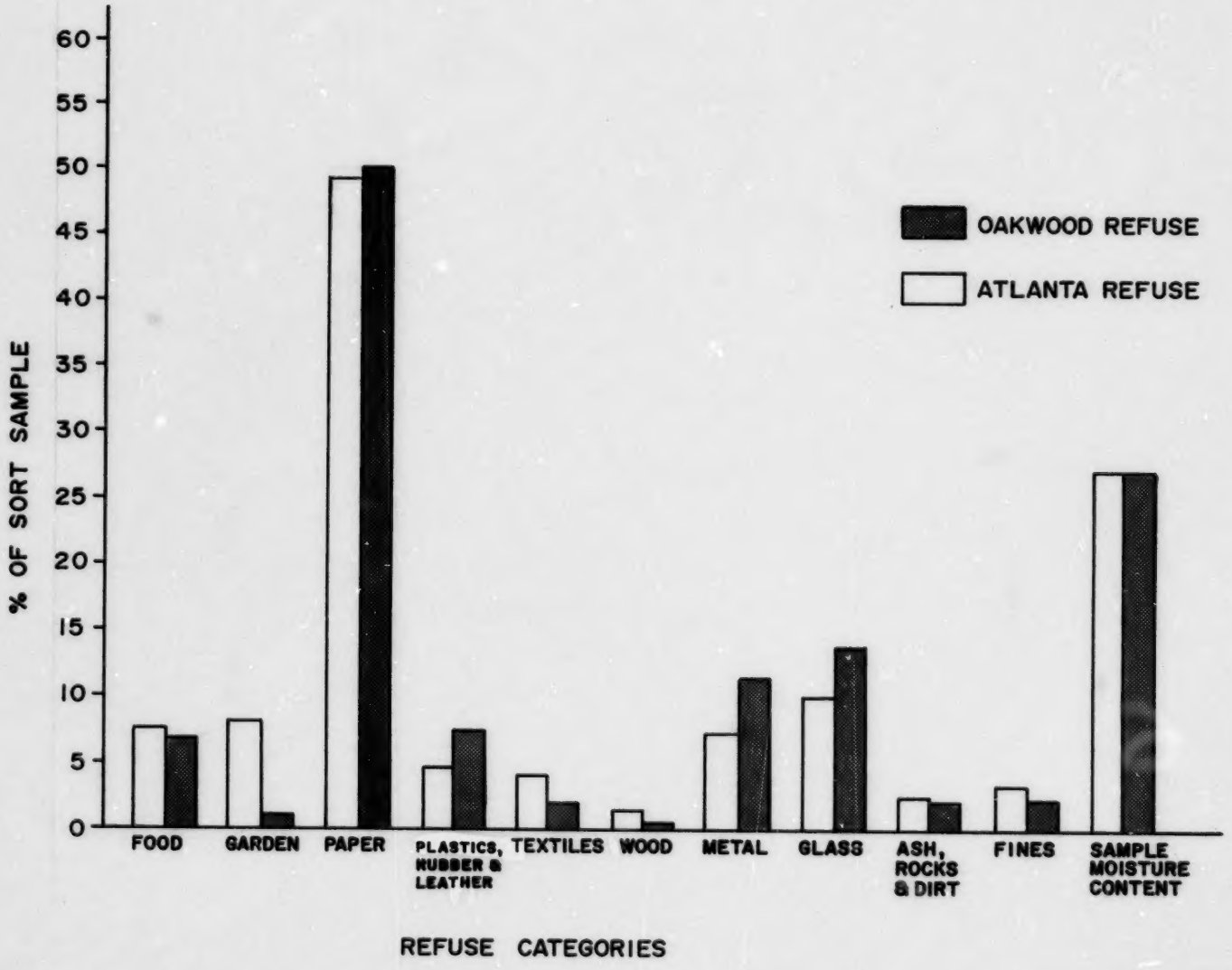

Figure 4. Refuse composition comparison.

Atlanta contractor was retained to band the bales. In order to facilitate handling at the Franklin test site, a 7.6-cm (3-in.) I-beam was banded into the bale so the bale could subsequently be moved, utilizing the I-beams and a crane.

With the resolution of the logistics problems, the baling and shredding of the municipal refuse started in Atlanta on December 16, 1974. The required handsorting of the representative solid waste samples was performed at both the shredding and baling facilities. These sorts were performed, utilizing local labor under the supervision of the contractor's personnel. The finished bales were received at the Franklin test site on December 19, 1974, and the loading, instrumenting, and sealing procedures were completed by December 20, 1974. The bales remained together during the shipment from Atlanta, and as bales were placed in the cells, the bands were removed. Other than this step, the loading and instrumentation procedures were identical to those described previously for the nonbaled wastes. It was necessary to use a clay backfill around the perimeter of the bales and at their junctions in order to prevent channeling by the leachate. The cell loading data for all cells are presented in Table 3.

The completion of the cell loading at Franklin was considered the end of the construction and cell charging portions of the program. With the completion of this step in the program, the monitoring phase officially began.

Operation of Test Cells

Cells 1, 2, 4, and 5 were operated on a monthly water addition and monthly volumetric leachate collection basis for approximately 5.8 years. The water additions were made according to a schedule resembling the annual rainfall pattern for the Midwestern United States. This schedule is shown in Table 4.

During the time period of the study, Cell 3 was operated under "saturated" conditions. During the initial period when the cell was slowly being saturated, sampling was accomplished by only withdrawing enough leachate to perform the required analyses. After achieving saturation, the leachate was drained monthly, and an amount of water was added which was equal to the volume of leachate withdrawn. Since no transpiration or evaporation takes place within these enclosed cells, the amount of moisture in Cell 3 is assumed to have remained constant.

Temperature data were taken twice a month until January 1979 when the digital readout burned out. Since enough data had been gathered to determine the precise yearly temperature fluctuations within the cells, it was not considered a necessary expense to have the unit repaired. Moisture monitoring data were taken along with the temperature data until February 1977, when it was determined that the moisture probes no longer operated in the higher moisture content of the cells.

Leachate samples have been collected since January 1975. The leachate was withdrawn from the bottom of each test cell via lines which have their terminus in the lower level of the instrumentation cell. Collection was

TABLE 3. CELL LOADING DATA

Weight categories*	Cell number 1	2	3	4	5
Silica gravel (15 cm)	2,324 kg (5,120 lb)	2,324 kg (5,120 lb)	2,324 kg (5,120 lb)	2,324 kg (5,120 lb)	2,324 kg (5,120 lb)
Refuse (3 layers of bales or 2.7 meters of compacted refuse)	11,662 kg (25,600 lb)	11,662 kg (25,600 lb)	11,662 kg (25,600 lb)	10,832 kg (23,840 lb)	9,716 kg (21,400 lb)
Clay backfill around bales†	14,039 kg (30,923 lb)	14,039 kg (30,923 lb)	14,039 kg (30,923 lb)		
Clay cover (15 cm)	3,251 kg (7,161 lb)	3,251 kg (7,161 lb)	3,251 kg (7,161 lb)	3,251 kg (7,161 lb)	3,251 kg (7,161 lb)
Pea gravel (30 cm)	1,639 kg (4,197 lb)	1,639 kg (4,197 lb)	1,639 kg (4,197 lb)	3,863 kg (8,393 lb)	3,863 kg (8,393 lb)
Total	33,142 kg (73,001 lb)	33,142 kg (73,001 lb)	33,142 kg (73,001 lb)	20,270 kg (44,514 lb)	19,154 kg (42,074 lb)
Refuse	853 kg/m^3 (1,452 lb/yd^3)	853 kg/m^3 (1,452 lb/yd^3)	853 kg/m^3 (1,452 lb/yd^3)	554 kg/m^3 (929 lb/yd^3)	496 kg/m^3 (840 lb/yd^3)

* All weights calculated except refuse wet weights for Cells 4 and 5.
† Clay backfill used around and between where necessary to prevent channeling.

TABLE 4. SCHEDULE OF WATER ADDITION

Month of year	Water to be applied: Centimenters equivalent water	gallons	liters
January	0	0	0
February	5.54	104.5	396
March	11.08	209	791
April	11.08	209	791
May	11.08	209	791
June	5.54	104.5	396
July	0	0	0
August	0	0	0
September	0	0	0
October	5.54	104.5	396
November	5.54	104.5	396
December	5.54	104.5	396

made from each of the cells on a monthly basis. The volume collected was recorded, and analytical procedures to determine chemical and biological parameters were carried out. This leachate withdrawal was always completed within a minimum of 2 weeks subsequent to water addition.

The pH of the leachates was measured, and the individual leachate samples were analyzed for chemical oxygen demand, total organic carbon, alkalinity, Kjeldahl nitrogen, total solids, and for the following metals: iron, copper, zinc, cadmium, chromium, lead, and nickel. In general, the analyses were completed according to methods described in Chian and DeWalle[1] because it was expected that the concentrations of many of these constituents would be so high in leachate that the more standard water and wastewater methods would be inappropriate.

The leachate collection in Cell 2, the baled waste, was noted to no longer correspond with the water additions dating from about August 1978. It was believed that the collection line was plugged, but the problem was not resolved even with various attempts to unblock the line over a period of several months. Extensive excavation in June 1979 revealed that the drain line had broken several feet from the test cell. The line was repaired and leachate collections were reestablished.

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[1] Chian, E. S. and F. B. DeWalle. "Compilation of Methodology Used for Measuring Pollution Parameters of Sanitary Landfill Leachate." Ecological Research Series, EPA/600/3-75-011, 1975.

Gas Monitoring

The initial plan was to collect the gas generated by utilizing nine perforated plastic pipes placed in the test cells within the body of the solid waste and one perforated pipe located in the head space of each test cell. These perforated pipes were connected to manifolds which passed through the walls of the test cell and led to the instrumentation cell. They were valved so that individual levels within the test cells could be sampled separately. Samples were drawn into glass sample tubes for gas chromatographic analysis. The analyses determined the O_2, CO_2, CH_4, and N_2 contents of the product gas. Gas volume was to be determined by combining all the gas loads from an individual test cell into one line which vents through a precision wet test meter.

One of the principal goals of the study was to determine the volume and composition of gas generated by decomposing MSW in a simulated landfill environment. Considerable effort was expended throughout the study in an attempt to obtain valid and meaningful gas volume data. Unfortunately, no reliable gas volume data have been generated by this study. The problems encountered were numerous, and they will be presented here in order that others may benefit by this experience.

The original plan of measuring the gas produced consisted of once each day drawing off the gas through the wet test meter by a vacuum pump. This technique is basically sound and has been used successfully by the contractor in laboratory studies of gas produced by anaerobic digester. However, the small volumes of gas produced in the early stages of the life of the landfill test cell were below the sensitivity of the test gas meters. When this problem was realized, a collection system utilizing impermeable gas bags for each test cell was devised.

Another problem that was encountered was gas leakage at the seals for the various lines penetrating the test cells; i.e., the ten gas collection lines, the water addition line, and the leachate collection line. Each of these exit points was originally sleeved and gasketed with room temperature vulcanizing (RTV) silicone. Apparently, over the period of years in which the test was conducted, these seals deteriorated and failed.

The cell cover was a precast concrete slab. Both the cover and the cell wall tops were apparently nonuniform to the point that the polyvinyl tubing that was used for gasketing was insufficient. Finally, the manhole in each of the cell covers was insufficiently gasketed. Each of these points was a potential gas leak, and nearly every one of these points proved to be a source of gas leaks. The lower two rows of three gas lines were disconnected from five test cells, and the bulkhead fittings were sealed in an attempt to minimize leaks. Only the top row of three probes inserted in the refuse was then used for gas sampling. However, it was discovered that within Cell 5, the nonprocessed refuse cell, these probes had been broken off by settlement of the waste. Because the clay and gravel cover over the waste had settled below the level at which the probes were originally located, new probes were installed at the second row of bulkhead fittings.

SECTION 4

ANALYSES AND RESULTS

PHYSICAL PARAMETERS

Temperature

After the initial temperature changes due to the exothermic decomposition of the newly loaded waste material, the test cells uniformly exhibit a history of following the ambient outside air temperature with the bottom portion of the cell being warmer in winter and cooler in summer than the top. The vertical temperature varied 5- to 10-Centigrade degrees (9- to 18-Farenheit degrees). The upper level of the test cells experienced a seasonal temperature variation in the range of 30- to 35-Centigrade degrees (54- to 63-Farenheit degrees) while the lower level of the test cells experienced only a 15- to 20-Centigrade degrees (27- to 36-Farenheit degrees) seasonal temperature variation. This corresponds with data presented in the Sonoma County Study[2] and Anderson[3].

A comparison of the average monthly internal temperatures on a cell basis for the first 9 months of the project is made in Table 5. As can be seen from this table, the temperature differences between cells are minimal after approximately 3 months of landfill time. Temperature data gathered over the next 2 years continued to confirm this initial data. It was therefore concluded that temperature changes are not considered a major influence factor on the test data acquired throughout this program.

The gypsum block probes measure moisture content as a percent of a meter reading of 100 on the moisture probe meter scale. This full scale meter reading roughly corresponds to saturation with the moisture probe. Calibration testing was done by immersing these probes in water to determine the maximum reading. After 3 months immersion, readings of approximately 98 units out of a possible 100 were obtained, indicating a saturated probe.

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[2] Emcon Associates. Sonoma County Solid Waste Stabilization Study. EPA/530/SE-65d. 1, U.S. Environmental Protection Agency, Washington, DC, 1975. 276 pp.

[3] Ham R. K., and C. R. Anderson. "Pollution Production by Refuse Degradation in Test Cells." Waste Age, December 1974.

TABLE 5. CELL-TO-CELL TEMPERATURE COMPARISON*

Month		Cell Number 1	2	3	4	5	Ambient
11/74	T	Cell not in place.			8.8	2.8	+0.8
	M				12.0	5.5	
	B				16.8	7.3	
12/74	T	16.8	10.8	9.0	6.6	3.9	0.8
	M	27.9	16.7	18.0	13.9	8.0	
	B	28.6	19.3	16.1	16.5	10.3	
01/75	T	6.1	4.5	3.4	4.0	3.3	+3.0
	M	11.6	9.3	8.8	8.2	6.5	
	B	12.2	10.4	10.1	10.8	8.7	
02/75	T	3.9	3.1	3.8	3.8	3.4	+4.1
	M	6.5	5.7	6.0	6.8	5.5	
	B	8.8	8.6	9.2	9.2	7.8	
03/75	T	4.1	4.2	4.7	4.4	4.3	+6.5
	M	5.1	5.0	5.7	5.8	5.0	
	B	6.9	7.3	7.7	7.8	7.1	
04/75	T	8.1	8.3	8.8	7.9	8.2	+13.7
	M	8.1	7.6	7.9	7.7	7.5	
	B	8.1	8.6	8.9	8.6	8.7	
05/75	T	20.7	21.2	22.3	19.0	18.6	+26.4
	M	15.4	15.6	16.0	14.0	14.2	
	B	12.8	13.3	14.2	13.2	13.5	
06/75	T	25.6	25.6	26.6	24.8	24.5	+32.9
	M	21.2	21.0	21.5	19.1	19.5	
	B	16.7	16.9	18.0	16.4	16.5	
07/75	T	29.4	30.0	30.8	28.8	28.4	+34.8
	M	25.4	25.4	26.6	23.4	23.8	
	B	20.2	20.6	22.2	20.4	20.8	
08/75	T	29.3	29.3	29.7	28.7	28.3	+31.3
	M	26.3	26.3	27.0	25.3	25.3	
	B	22.0	22.0	23.7	22.0	21.7	

* Average temperature in °C.

NOTE: T indicates top layer measurement
M indicates middle layer measurement
B indicates bottom layer measurement

Under actual test conditions, there was a high failure rate of the gypsum block moisture probes. Possible reasons for this failure rate include:

1. corrosion of the electrodes in the probes, or
2. breakage or degradation in the gypsum blocks, or
3. failure of the joint connecting the leads of the electrodes.

While the moisture probes did suffer a high mortality rate, they did serve to indicate that moisture was relatively uniform throughout the cells Of greater importance is the comparison of the effect of preprocessing on the moisture retained values of the different landfill test cells when infiltration water is added.

The theoretical field capacity of refuse is its absorptive capacity for moisture. Therefore, in theory, the amount of water infiltrating a landfill should equal the quantity of leachate exiting the landfill once field capacity is reached. In a practical, real world situation however, the definition of apparent field capacity as reported by Fenn et al[4] is more appropriate to the problem. Fenn defines field capacity as the maximum moisture content which a soil (or solid waste) can retain in a gravitational field without producing continuous downward percolation. The data in this report are presented in terms of "field capacity" meaning the initiation of continuous leachate production.

The total apparent moisture retained within the cell is inferred directly from the volume of water added minus the volume of leachate removed. As the test cells are enclosed, transpiration and runoff do not enter into the calculation. The apparent moisture retained in the cell was calculated as follows:

$$M = \frac{1000\ (R - L)}{G}$$

Where:
M = apparent moisture retained (mℓ/kg),
R = water added (liters),
L = leachate removed (liters),
G = kg dry solid waste.

Moisture Analyses and Results

A summary of the moisture balance data for the cells containing wastes not saturated with moisture is presented in Table 6. These data indicate that the waste processing procedures had an effect on the start of

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[4] Fenn, D. C., K. J. Hanley, and T. V. DeGeare. Use of the Water Balance Method for Predicting Leachate Generation From Solid Waste Disposal Sites. EPA/530/SW-168, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1975.

continuous leachate production. The processed wastes started producing leachate before the nonprocessed waste. The processed wastes in Cells 1, 2, and 4 began producing leachate in the fifth, second, and fourth months, respectively; while the nonprocessed refuse, Cell 5, began producing leachate in the sixth month.

TABLE 6. MOISTURE BALANCE SUMMARY

	Moisture retention data (mℓ/kg refuse)			
Data	Cell 1 (Shredded, baled) (5/75*)	Cell 2 (Baled) (2/75*)	Cell 4 (Shredded) (4/75*)	Cell 5 (Nonprocessed) (6/75*)
12/75	306	316	475	579
12/76	406	426	672	797
12/77	520	548	814	968
12/78	737	774	1,131	1,299
12/79	854	851	1,198	1,309
7/80	924	913	1,242	1,378

* Date continuous leachate production began.

It is also shown that the nonbaled wastes have retained substantially more moisture than the baled refuse. The moisture retained values for the baled wastes are very similar in magnitude. The nonprocessed refuse has retained more moisture than both the shredded waste and the baled wastes.

The results indicate that baling of refuse has an inhibitory effect on its moisture retention capability. The tightly-packed bales are more difficult for water to infiltrate than loose refuse, so absorption of water proceeds at a slower rate. Shredding of refuse is also shown here to decrease moisture retention, but to a much lesser degree than baling. While Fungaroli[5] reported that milling (shredding) of refuse greatly increases the saturated field capacity, this phenomenon was not observed during this evaluation. A possible explanation is that the shredded waste may not have achieved its complete field capacity. Fungaroli also noted that increasing

[5] Fungaroli, A. A. Investigation of Sanitary Landfill Behavior. EPA-600/2-79-053 a&b. U.S. Environmental Protection Agency, Cincinnati, Ohio, June 1979.

the density of milled refuse (by making smaller particles) increases the amount of that refuse remaining at a moisture content less than field capacity. The implication of this phenomenon is that dry parcels occur within the refuse mass. As described in Appendix C, verification of this hypothesis was made when the test cells were opened and the refuse examined.

The moisture balance figures also show that the rates of moisture absorption by the nonbaled wastes in Cells 4 and 5 slowed considerably compared to the baled wastes. The nonbaled wastes (Cell 5) retained only a little more moisture at July 1980 than they did at December 1978. This indicates that the nonbaled wastes were reaching their field capacities.

VOLUMES OF LEACHATE AND GAS GENERATED

Because the wastes in each of the five cells were mechanically processed differently before "landfilling," the refuse differ in water retention ability. As seen in Figure 5, the refuse did not produce equal volumes of leachate even though equal volumes of water were added to them each month. The largest amounts of leachate emanated from Cells 1, 2, and 3 containing the baled wastes. Much smaller leachate volumes were drained from the shredded waste, and the least volume of leachate emanated from the nonprocessed waste. The observations in this figure and in Table 6 indicate that the production of leachate by the cells is inversely proportional to moisture retention, but the volume of leachate produced alone is not indicative of its pollution potential. The leachates from the baled refuse contained less pollutants per liter than the leachate from the shredded nonbaled refuse. The concentrations of the measured pollutants in the leachate and also the cumulative masses of pollutants in the leachate are found to be the least in the baled waste and the greatest in the shredded nonbaled waste. Each specific pollutant and its leachate concentration will be discussed in detail in the following section under "Chemical Parameters."

Very little gas production data are available from the literature for comparisons, and no literature has been published thus far relating to gas production from baled refuse in a quantitative sense. However, it has been estimated that each kilogram of refuse during decomposition is capable of producing 167.0 liters of carbon dioxide and 241.7 liters of methane for a total of 408.7 ℓ/kg of refuse. It is believed that landfill system efficiencies may result in conversions of between 25 to 72 percent[6] of the theoretical maximum amount or 62.7 to 187.2 liters of methane per kilogram of refuse decomposed. When CO_2 is included, the total gas production from a pound of refuse is estimated to be in the range of 105.8 to 308.7 ℓ/kg decomposed. Since the weights of refuse are accurately known for these test cells, the theoretical production rate of gas can be calculated assuming an estimated life of the landfill. If the life of the landfill is assumed to be

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[6] Pacey, J. G., R. S. Altmann. " Methane Gas in Landfills Liability or Asset?," Municipal Solid Waste Management Association Conference, November 1975.

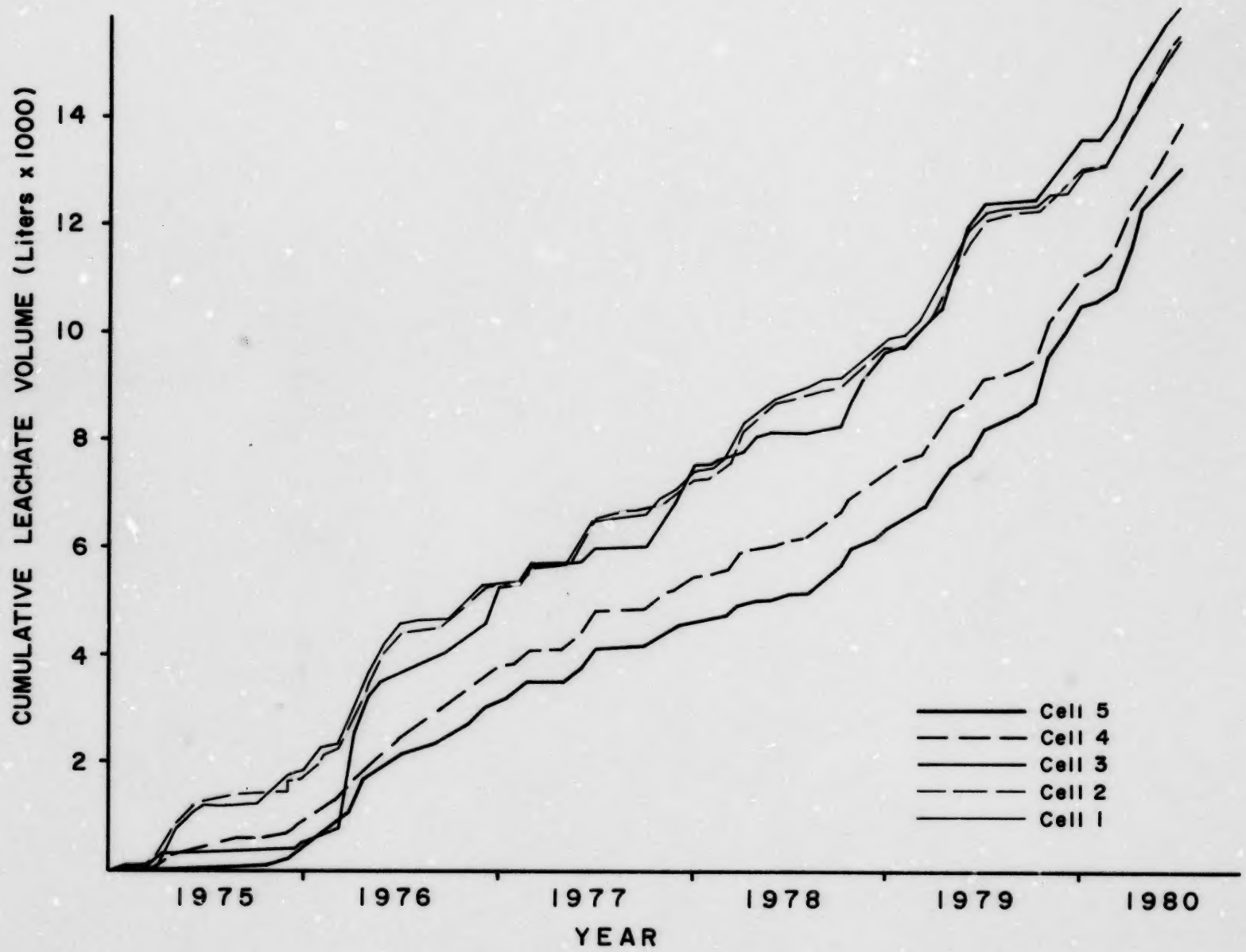

Figure 5. Cumulative leachate volumes versus time.

10 years, then the gas production rates shown in Table 7 should theoretically hold.

TABLE 7. THEORETICAL GAS PRODUCTION RATE

Cell number	Refuse weight	Gas production (in liters)			
		Total ($\times 10^{-3}$)		Per day (over 10 years)	
		Minimum	Maximum	Minimum	Maximum
1	11,662 kg (25,600 lb)	1,233	3,600	337	1,000
2	11,662 kg (25,600 lb)	1,233	3,600	337	1,000
3	11,662 kg (25,600 lb)	1,233	3,600	337	1,000
4	10,832 kg (23,840 lb)	1,146	3,344	314	940
5	9,716 kg (21,400 lb	1,028	3,000	282	850

Other literature gas production rates for test cells are as follows:

Literature gas production rates[7]

Initial (0 to 3 days):	Intermediate (230 to 530 days):
27 mℓ/kg/day	14 mℓ/kg/day

Despite extensive efforts to seal the in-ground test cells at the Franklin test site, the conclusion was finally reached that it was an impossible situation. It should be noted that effective sealing was accomplished for short periods during the course of the study and that some gas volume data were generated during those periods. However, the possibility of intermittent failures of gas seals must lead to the conclusion that none of the gas volume data should be considered scientifically reliable.

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7 "Quantitative Study of Gas Produced by Decomposing Refuse." Public Works, 99(11):86-87, November 1968.

CHEMICAL PARAMETERS

Leachate Composition

The differences in waste composition among the cells and the differences in leachate volumes produced necessitate the use of some basis to compare leachate pollutants. The most meaningful measure of leachate quality for our purposes is the total mass of specific pollutant emanating from each cell per kilogram of dry solid waste. This is calculated by multiplying the measured concentration of pollutant by the volume of leachate, divided by the total mass of dry solid waste placed in the test cell.

Since the wastes do not produce equal volumes of leachate in the same month, the cumulative masses of pollutants from each cell can be compared on a basis of leachate volume or a basis of time. In comparing mass removals of a pollutant on a leachate volume basis, the cumulative mass removed by a standard volume of leachate is compiled for each cell. The same volume of leachate is used for all the cells, so the cell releasing the most concentrated leachate will have the largest mass removal. Comparing mass removals on a time basis does not take into account the volumes of leachate emanating from the cells; it only considers the total mass of pollutant removed in a given time period. More pollutants may be removed in a small volume of concentrated leachate than in a large volume of dilute leachate.

Table 8 contains the cumulative masses of leachate parameters removed from the cells on an equal leachate volume basis. The numbers shown are the total masses of contaminates removed in 13,147 liters of leachate. This is the total volume of leachate which has thus far emanated from Cell 5 (the nonprocessed waste). It is seen that the shredded waste in Cell 4 has the greatest mass removals of four of the first five parameters (alkalinity, total solids, TOC, TKN, and COD) and has the second largest mass removal of TKN. This finding was expected since shredding of refuse makes infiltration of water more rapid, accelerating the decomposition process. Conversely, baling of refuse inhibits water infiltration and produces a more dilute leachate. Cells containing baled refuse (Cells 1 and 2) have lower mass removals of the first five parameters than the other three cells. The cell with baled, saturated waste (Cell 3) has mass removals roughly equivalent to those of nonprocessed refuse. It may be that the saturation of the baled refuse in Cell 3 has overcome the inhibition of moisture infiltration normally produced by baling, thus causing more leaching of pollutants than would usually be expected from baled refuse. The mass removal values for the baled, saturated waste and the nonprocessed waste are generally between the values for the baled, unsaturated wastes and the shredded waste.

When comparing the cumulative masses of metals leached from the cells in Table 8, it should be noted that most of these metals have been detected in only trace amounts in the monthly leachate samples. This means that any analytical error in the detection of these metals would have a greater effect on the calculated cumulative mass leached than an error in the analysis for a leachate parameter which has a high concentration, such as TOC or COD. Small variations in the metals content of the refuse among cells would then cause a

TABLE 8. CUMULATIVE MASSES OF LEACHATE PARAMETERS PER KG DRY REFUSE ON A BASIS OF EQUAL LEACHATE VOLUME

	Cell number				
	1 (shredded, baled)	2 (baled)	3 (baled, saturated)	4 (shredded)	5 (unprocessed)
Alkalinity, mg/kg	5,450	6,960	9,420	17,200	9,280
Total solids, mg/kg	10,500	15,200	21,200	40,200	24,200
TOC, mg/kg	6,040	9,950	13,300	21,700	16,500
TKN, mg/kg	241	411	514	712	729
COD, mg/kg	9,230	23,200	36,000	50,000	34,600
Iron, mg/kg	273	714	1,180	1,940	540
Copper, µg/kg	149	152	490	152	128
Cadmium, µg/kg	60	76	78	112	84
Zinc, mg/kg	13	20	10	200	42
Nickel, µg/kg	539	789	1,060	1,950	759
Chromium, µg/kg	246	304	305	284	167
Lead, µg/kg	598	654	564	856	577

large effect in the composition of the leachate. In many instances, the concentration of a metal was below the detection limit of the method. Rather than taking the concentration as 0 mg/ℓ, the detection limit itself was taken as the concentration, and the total mass of metal leached was calculated from that value. The table, therefore, reflects the maximum amount of metal that may have leached based on known detection limits. Up to 50 percent of each of the cumulative mass-leached values for copper, cadmium, nickel, chromium, and lead may reflect amounts that were below the detection limits.

Just as the cell with shredded, nonbaled waste (Cell 4) had the greatest mass removals for the first five parameters, it also has the greatest mass removals of five of the seven metals. The high relative numbers for iron and zinc especially point out the enhanced rate of leaching caused by shredding of the waste. In general, the metals results do not show the inhibition of leaching by baling of the waste since the baled unsaturated wastes (Cells 1 and 2) have mass removals approximately the same as those of the control (Cell 5). Only the mass removals of zinc from Cells 1 and 2 are clearly indicative of a reduced rate of leaching when compared to the cumulative zinc emanated from the control cell (Cell 5). The great deal of variability in the metals results is probably caused by the large error possibilities associated with the detection of very low concentrations of copper, cadmium, nickel, chromium, and lead in the leachates. Since the amounts of these metals are low in the waste placed in the test cells, much relative variation may be present from cell to cell in the quantity of metal originally available for leaching. This makes meaningful comparisons among the cells for these parameters difficult, if not impossible.

The plots of cumulative-masses-of-pollutants-leached vs. cumulative-leachate-volume and vs. time (see Figures 6 through 15) further indicate the effects of the waste processing procedures. In every case, the shredded refuse (Cell 4) has had more mass leached than the waste processed by other means. The shredding has increased the surface area of the waste and enhanced moisture infiltration, providing more sites for biological and chemical activity. The baled wastes of Cells 1 and 2 have had less cumulative masses removed than the nonprocessed waste (Cell 5) showing the inhibition of moisture infiltration and leaching caused by baling of the waste.

Looking again at the cumulative masses of pollutants leached from the cells on an equal leachate volume basis (as shown previously in Table 8), it is interesting to compare the data from Cells 1 and 2. Both cells contain baled refuse, but the refuse in Cell 1 was shredded before baling. A greater mass of every pollutant has leached from the baled nonshredded refuse than from the shredded, baled refuse. Also, more than twice as much COD has leached from the baled nonshredded refuse than from baled, shredded refuse. It appears that baling of shredded waste produces bales that are even more resistant to leaching than bales of nonshredded waste. Reducing the size of refuse particles allows them to "fit together" more compactly in bales, reducing air space between particles more than simple baling. This process would further retard movement of water in and solids out, resulting in a lower rate of leaching for baled shredded waste than for baled waste. The increased rate of leaching from Cell 2 over Cell 1 is also readily evident in the plots of cumulative masses leached vs. cumulative leached volume.

One of the metals deserves special mention in our discussion because of its high rate of leaching from the shredded, nonbaled waste, Cell 4. High rate is defined as relative to the other test cells. The cumulative mass of zinc leached from Cell 4 is about one order of magnitude higher than that of the other cells. The presence of zinc alkaline batteries in the waste may be responsible for this phenomenon, according to Hentrich.[8] The batteries contain zinc salts which would normally be sealed within, unless the battery were shredded. The zinc salts which would then be released and available for leaching. Such batteries would also have been shredded in the waste of Cell 1, but the baling of the waste would hinder leaching of the salts by making the wastes more impermeable to water. Rapid leaching of zinc in Cell 1 has not been observed. The disproportionately large significance of this one component of the waste stream points out how minor variations in the compositions of wastes can have great impacts on the character of the leachates emanating from them. However, these variations only assume great importance when the parameter being considered is usually present as a very minor component in the refuse.

The raw leachate composition data are presented in tabular form in Appendix A.

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[8] Hentrich, Jr., R. L., J. T. Swartzbaugh, and J. A. Thomas. "Evaluation of Landfilled Processed Municipal Wastes." Annual Report, EPA Contract No. 68-032598.

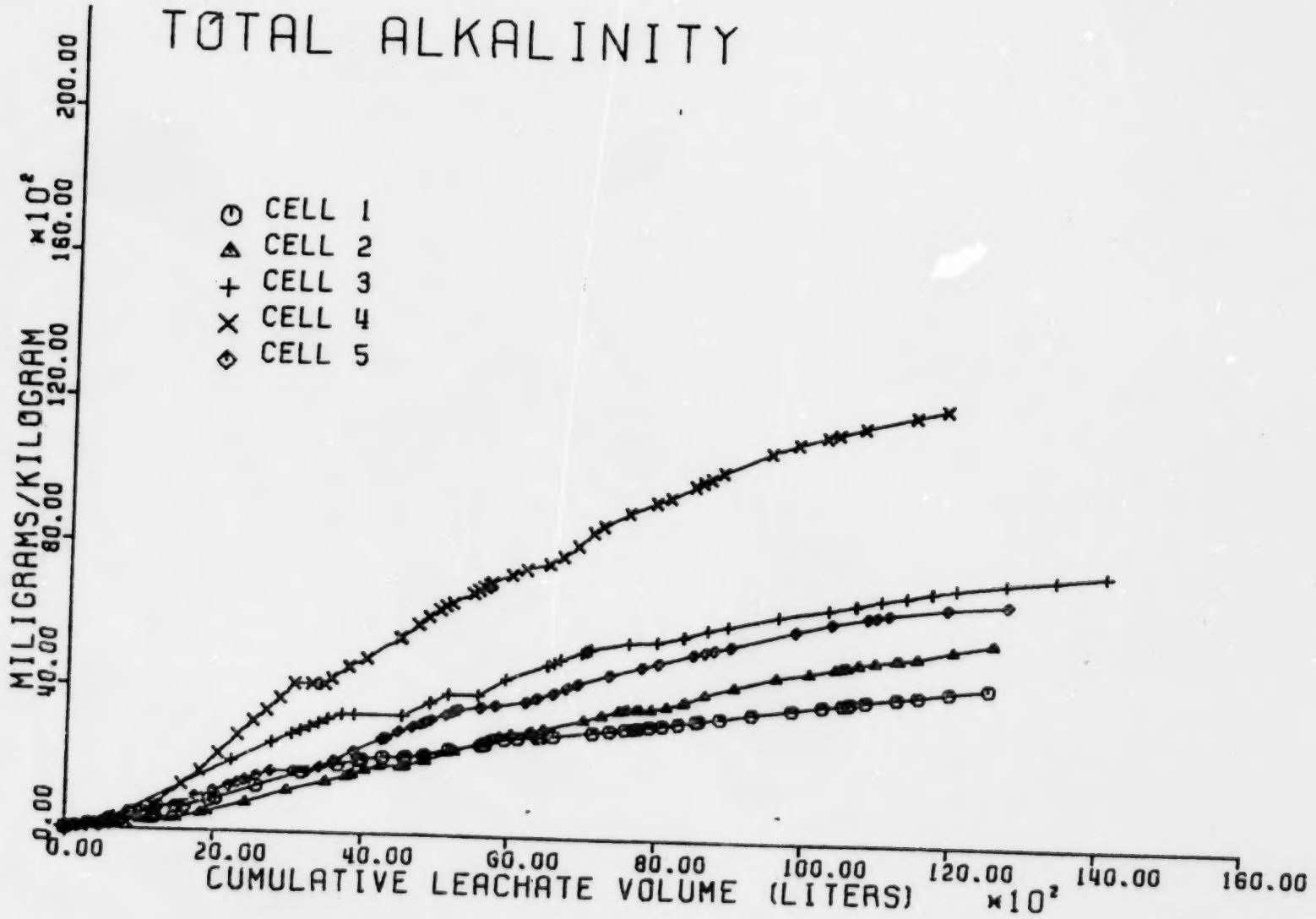

Figure 6. Total alkalinity - mass flow vs. cumulative leachate volume.

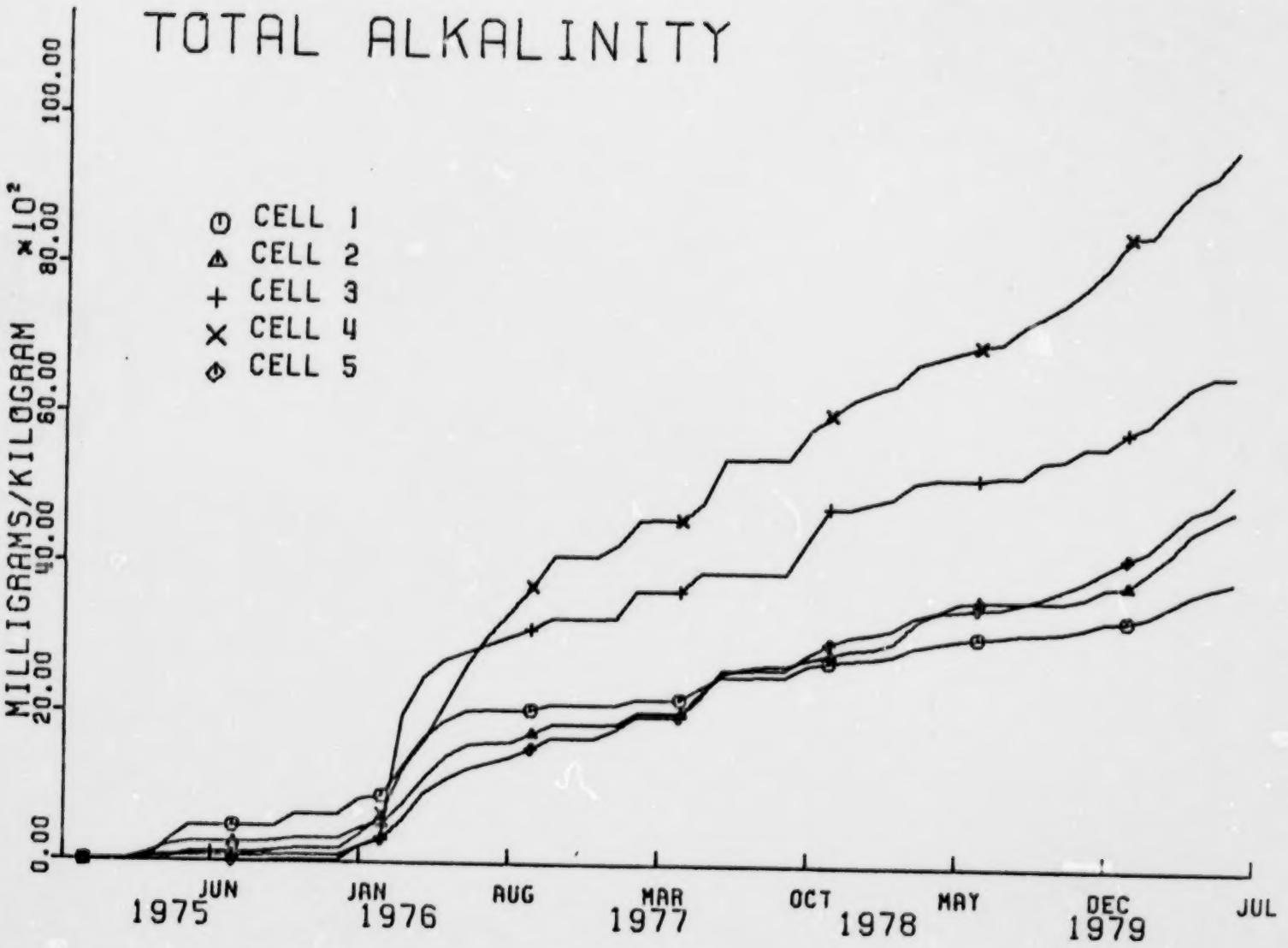

Figure 7. Total alkalinity - mass flow vs. time.

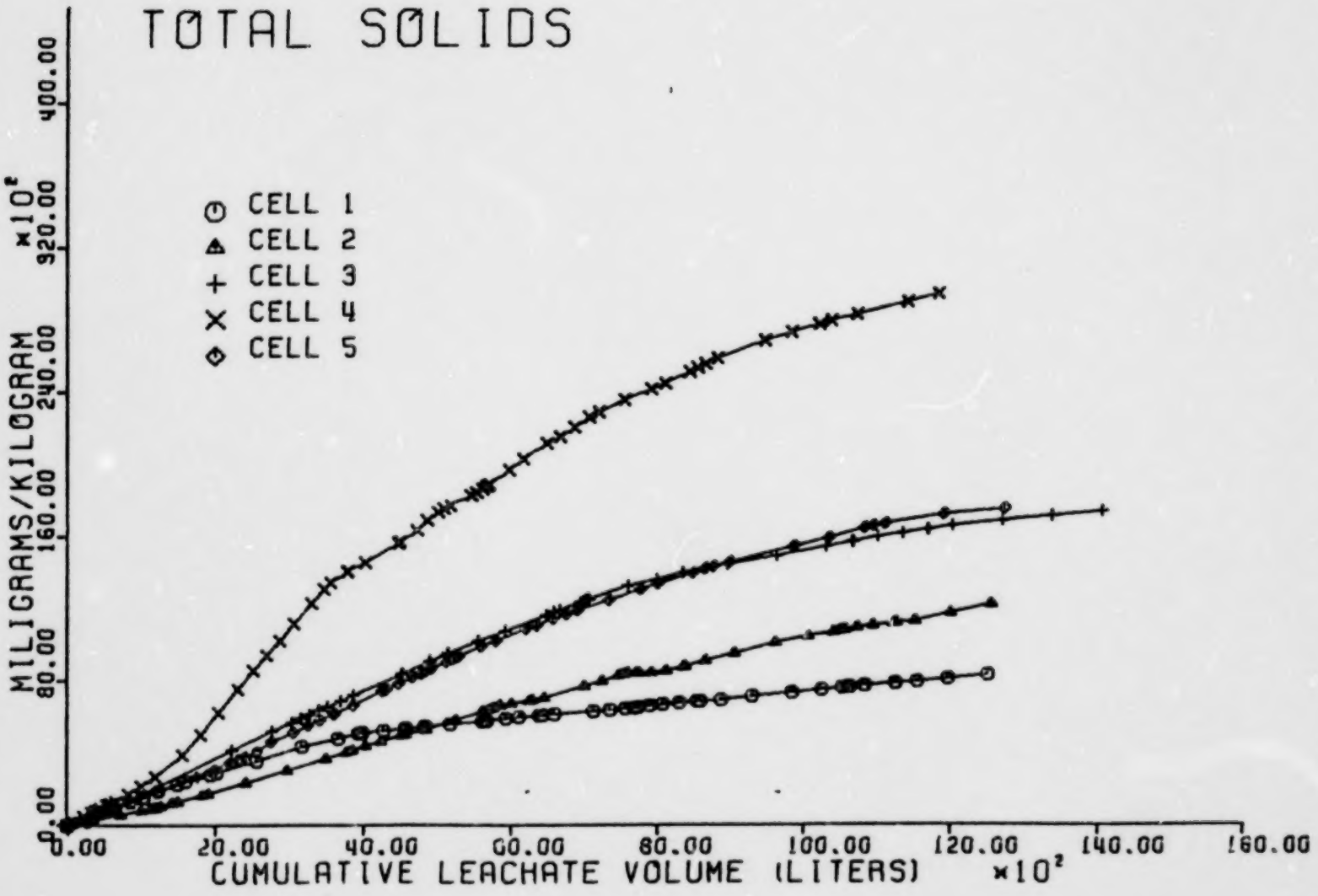

Figure 8. Total solids - mass flow vs. cumulative leachate volume.

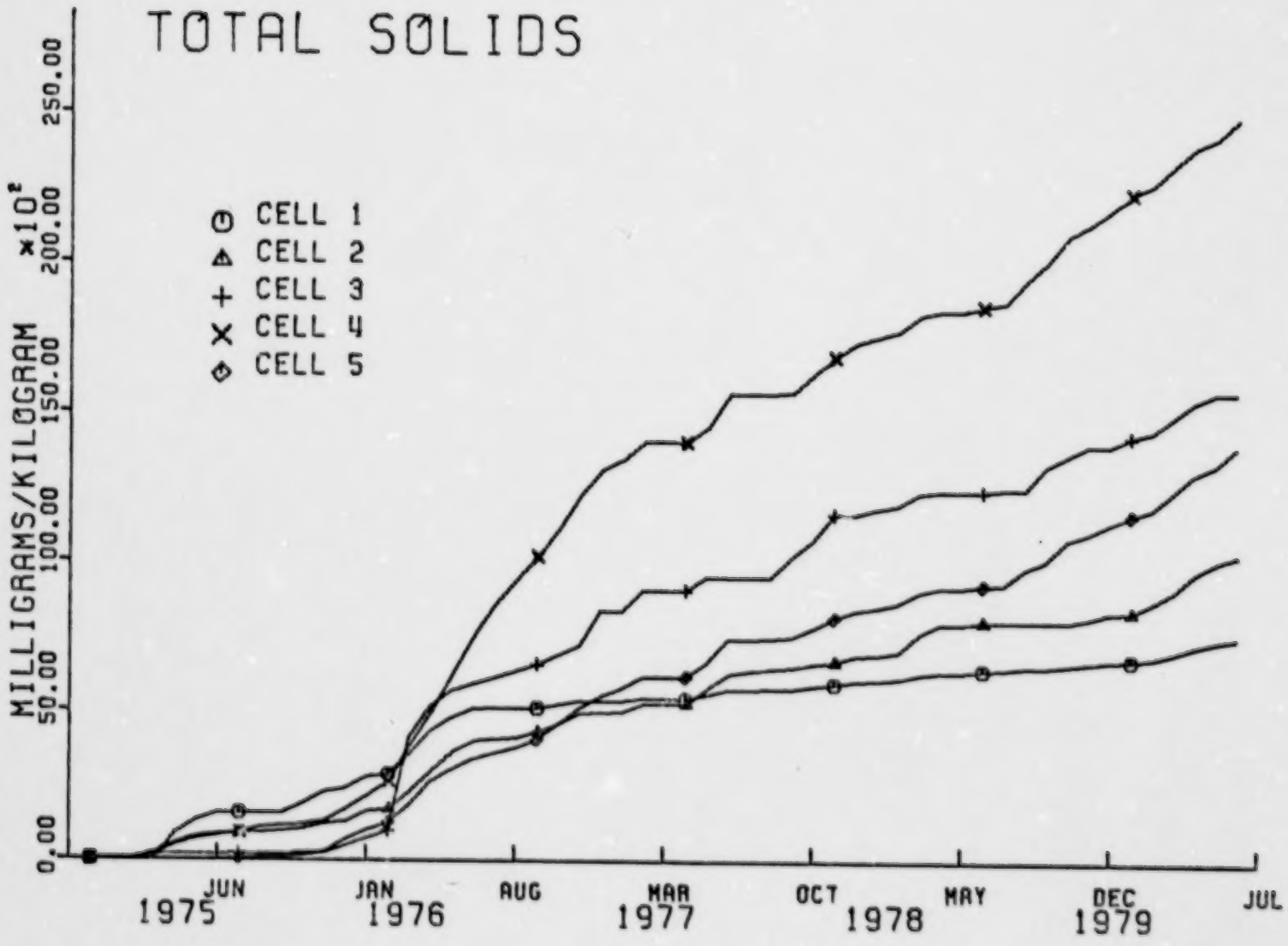

Figure 9. Total solids - mass flow vs. time.

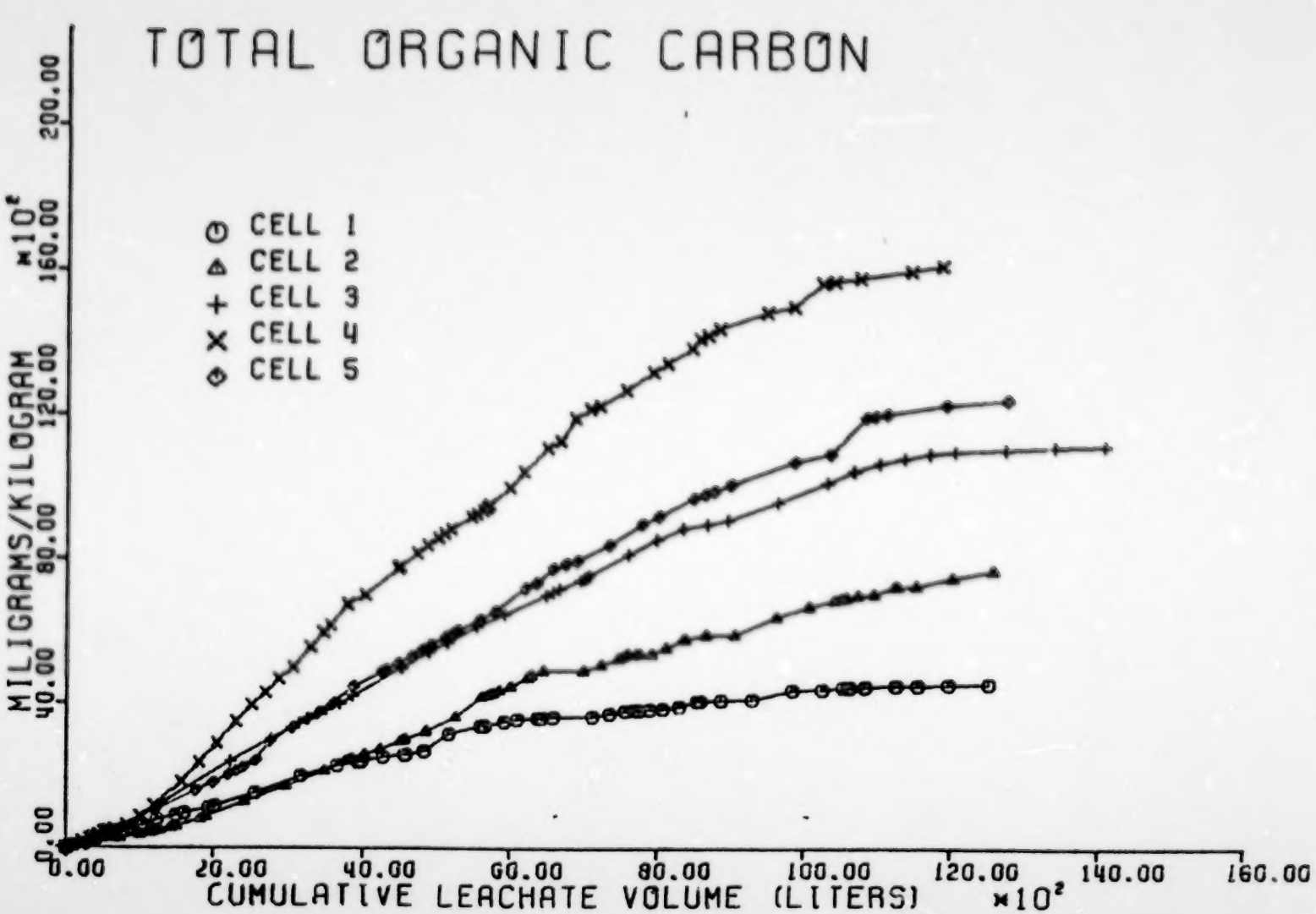

Figure 10. Total organic carbon - mass flow vs. cumulative leachate volume.

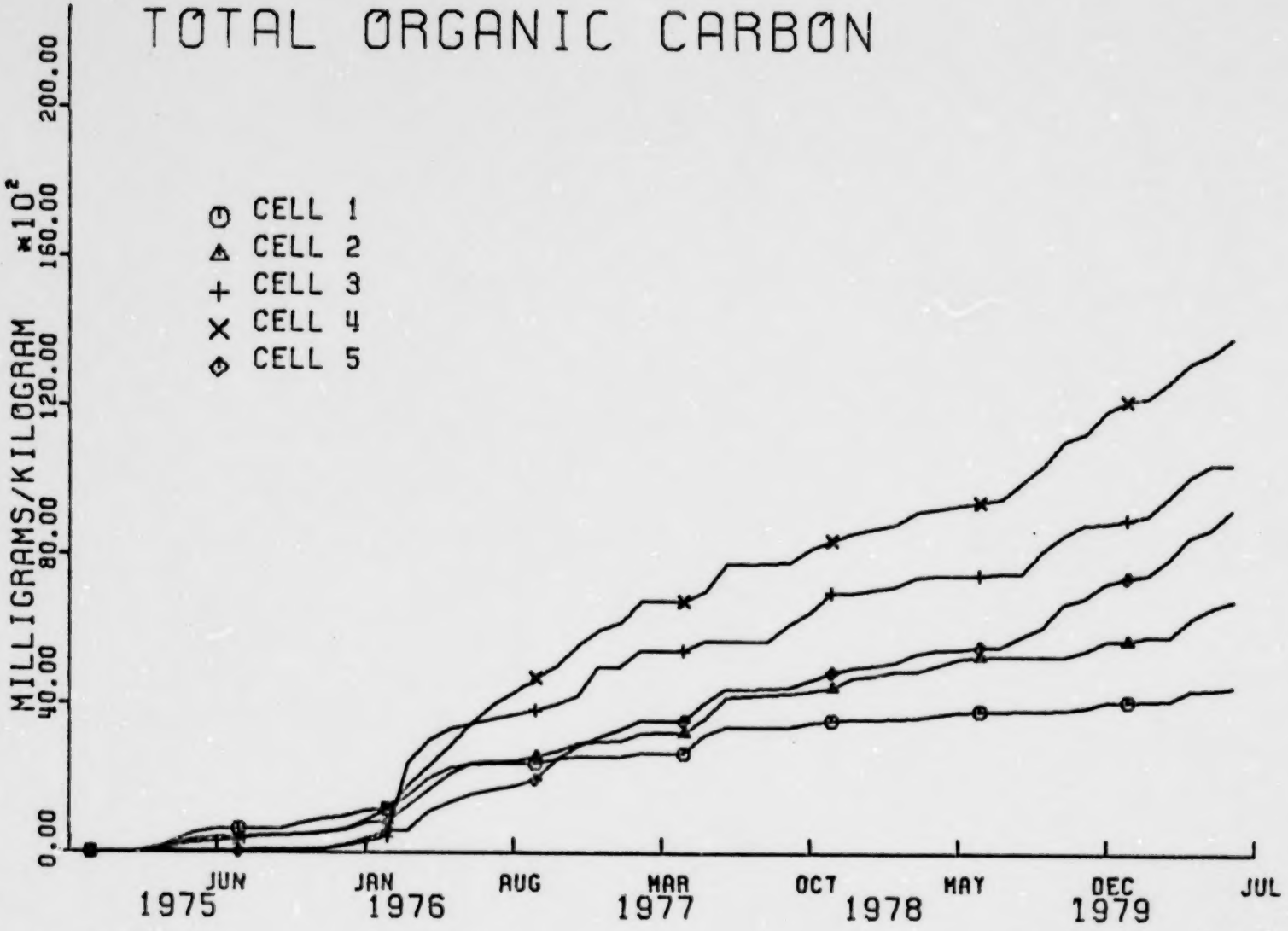

Figure 11. Total organic carbon - mass flow vs. time.

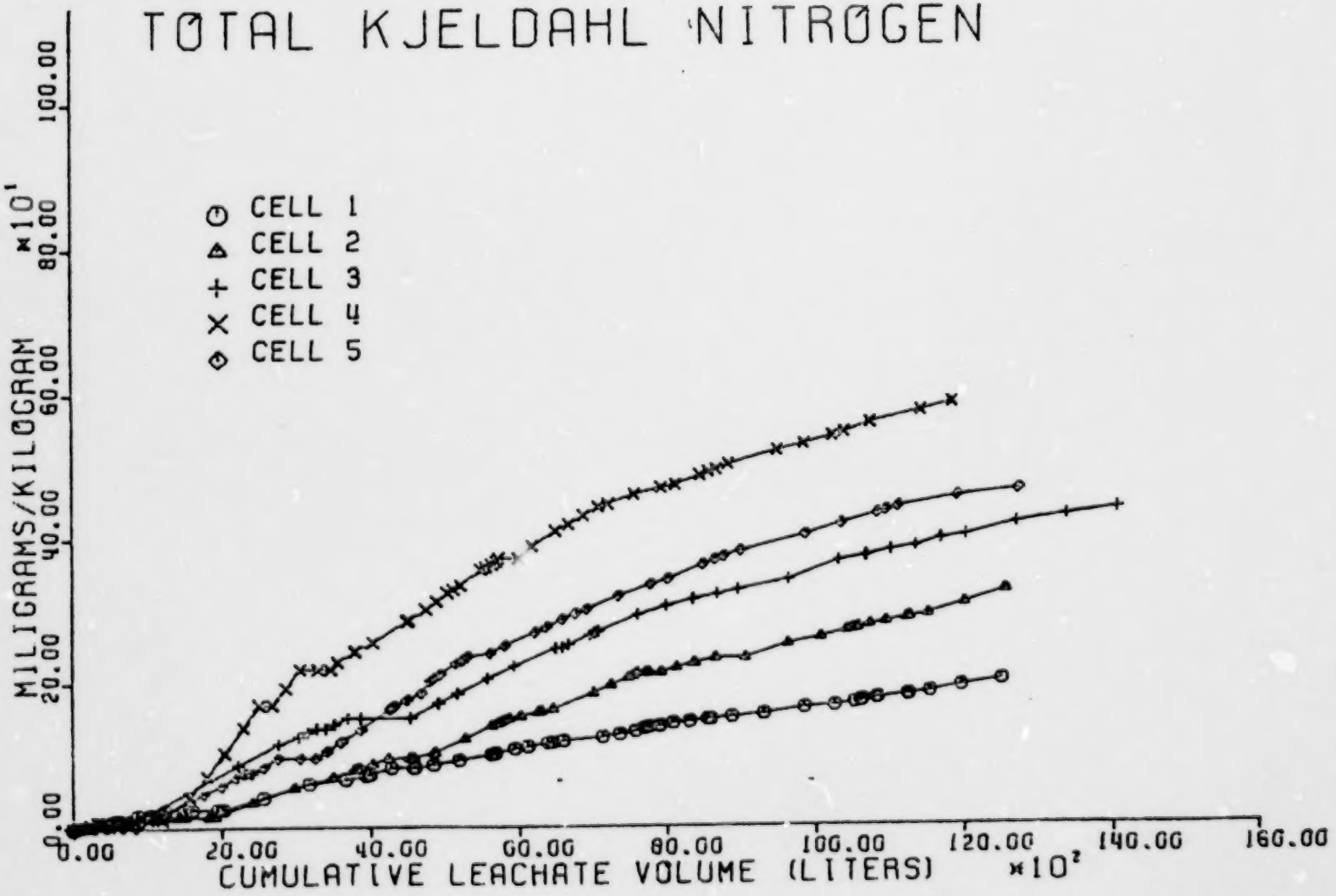

Figure 12. Total kjeldahl nitrogen - mass flow vs. cumulative leachate volume.

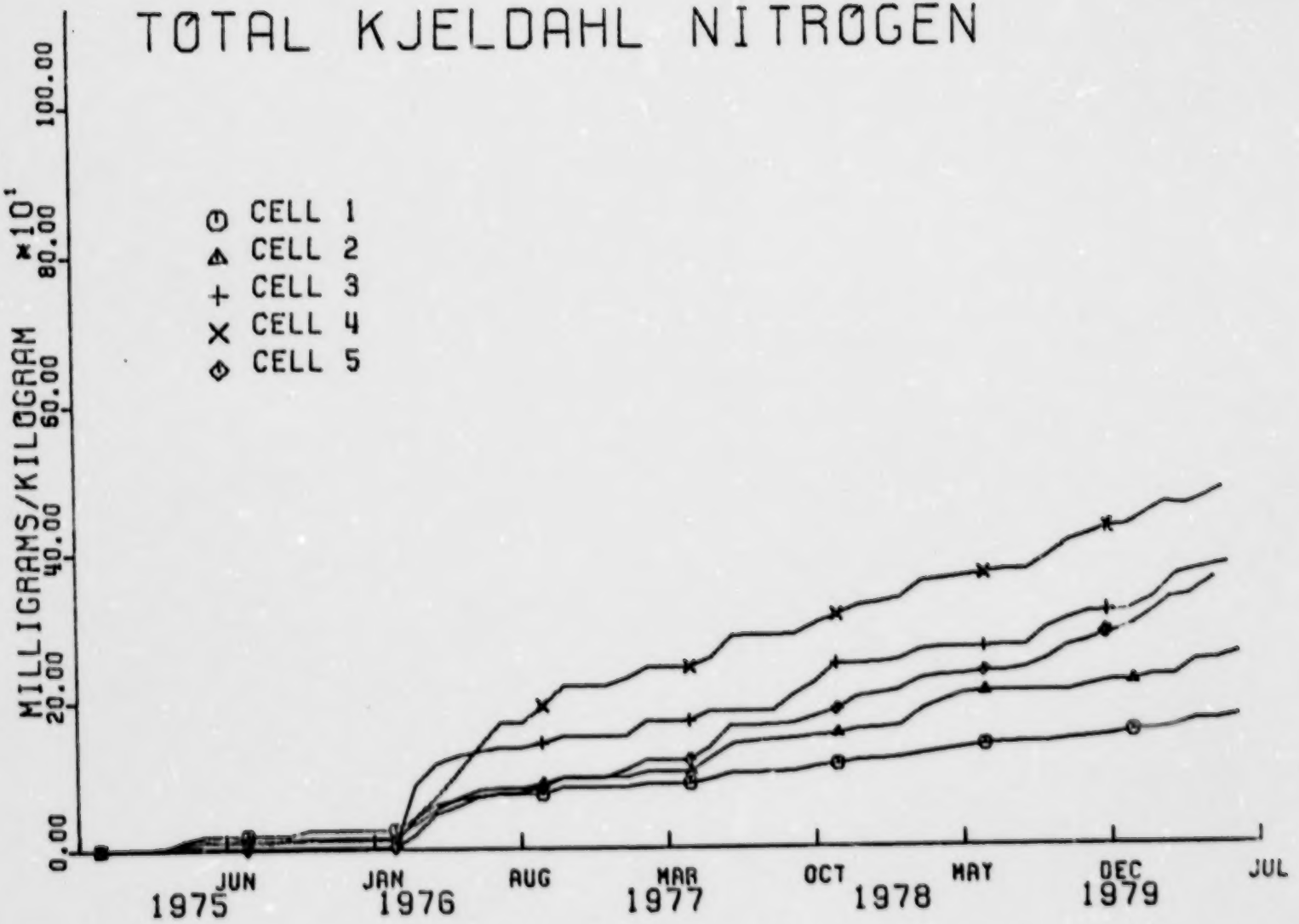

Figure 13. Total kjeldahl nitrogen - mass flow vs. time.

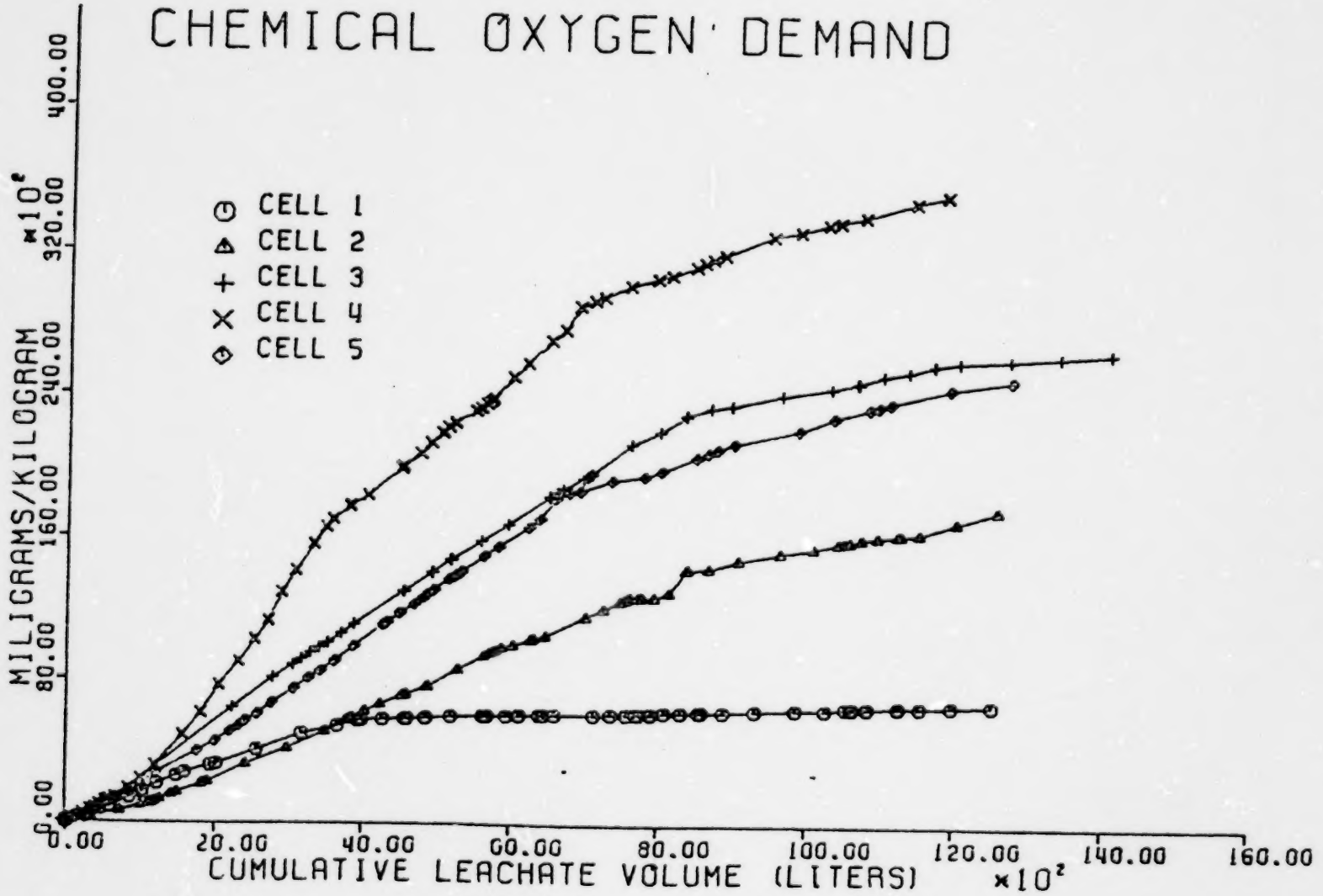

Figure 14. Chemical oxygen demand - mass flow vs. cumulative leachate volume.

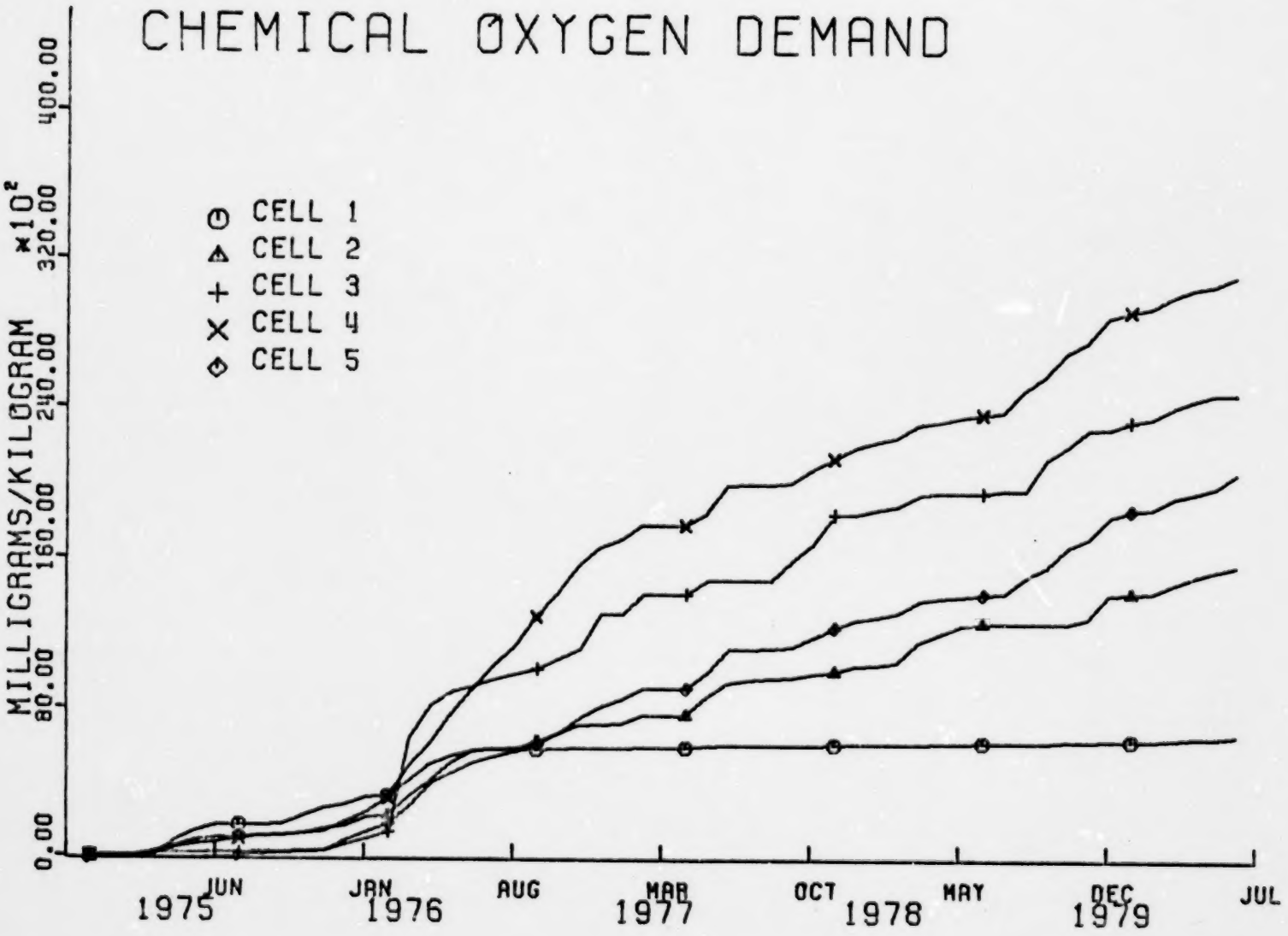

Figure 15. Chemical oxygen demand - mass flow vs. time.

Gas Composition

Figures 16 through 19 show time histories of the compositions of gases collected from the test cells. The graphs indicate variations both with time and from cell to cell. An anaerobic, methane-producing situation is indicated for refuse that has been shredded and baled (Cell 1), while the nonprocessed waste Cell 5 is shown to have produced little methane. Cells 2 through 4 have produced methane in varying amounts. The gas composition data are presented in Appendix B.

With regard to the failure of Cell 5 to produce methane, it seemed unbelievable that no portion of this large mass of nonprocessed waste had become anaerobic and produced methane. Therefore, the possibilities of blockages or leaks in the gas collection system of Cell 5 were investigated. Results of this investigation revealed that indeed the gas collection probes within the cell were found to have been broken off by settlement of the refuse. Where the gas collection lines penetrated the walls of the cell, they now met settled clay and gravel which had been placed originally over the refuse. To correct this, new gas collection probes were installed into the refuse mass. Samples taken after the installation of the new probes were as much anaerobic as those from the other cells (approximately 5 percent O_2), but still not in a methanogenic phase, since only traces of methane were detected. The pH of the leachate from the nonprocessed waste remained below 6, while the leachate from the other wastes were all above 6. This low pH suggested that the nonprocessed refuse was maintained in a state of acid fermentation with only a few methane-forming bacteria present. This would explain the lack of methane production, but just why the nonprocessed waste alone acted this way is unknown.

The gas composition data show some small similarities in seasonal changes among the cells. Cells 1, 2, and 4 especially have similarly shaped plots of gas composition vs. time. Increases, decreases, peaks, and valleys follow one another in much the same sequence for these three cells. This could be due to temperature variations of the same magnitudes in the cells at the same times or also due to dissolved oxygen in water added to the cells.

In general, the gas composition data do not indicate any obvious effects of the different refuse processing procedures. This study has not indicated any effects baling and shredding have on landfill gas production.

In conclusion, it must be kept in mind that the nature of the study and cost of the test cells did not allow for replication of the test cells. It is this lack of sample cell replication which necessitated the statistical analysis being made utilizing Dixon's Criterion rather than a statistical method based upon a population of replicates.

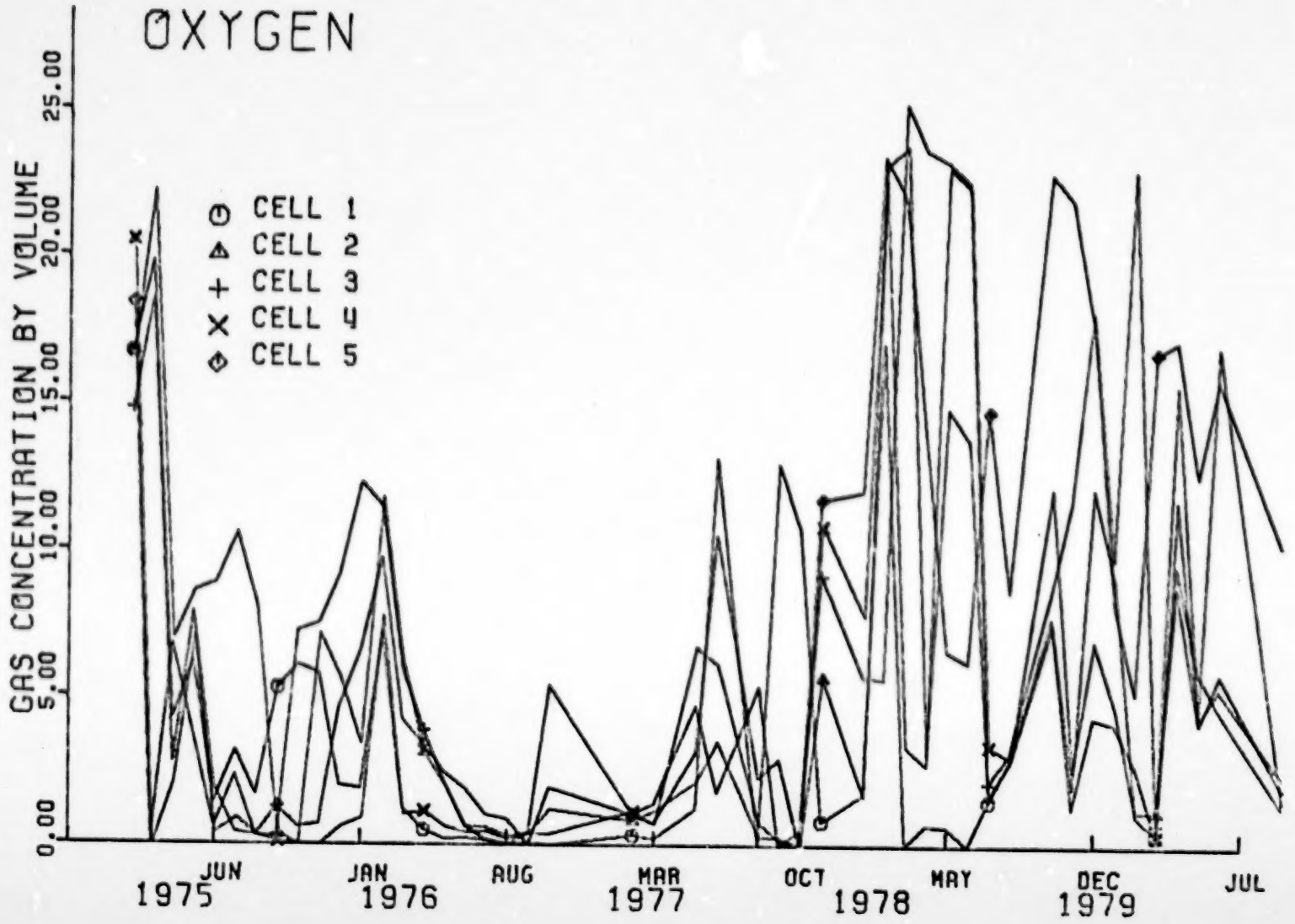

Figure 16. Oxygen - percent composition vs. time.

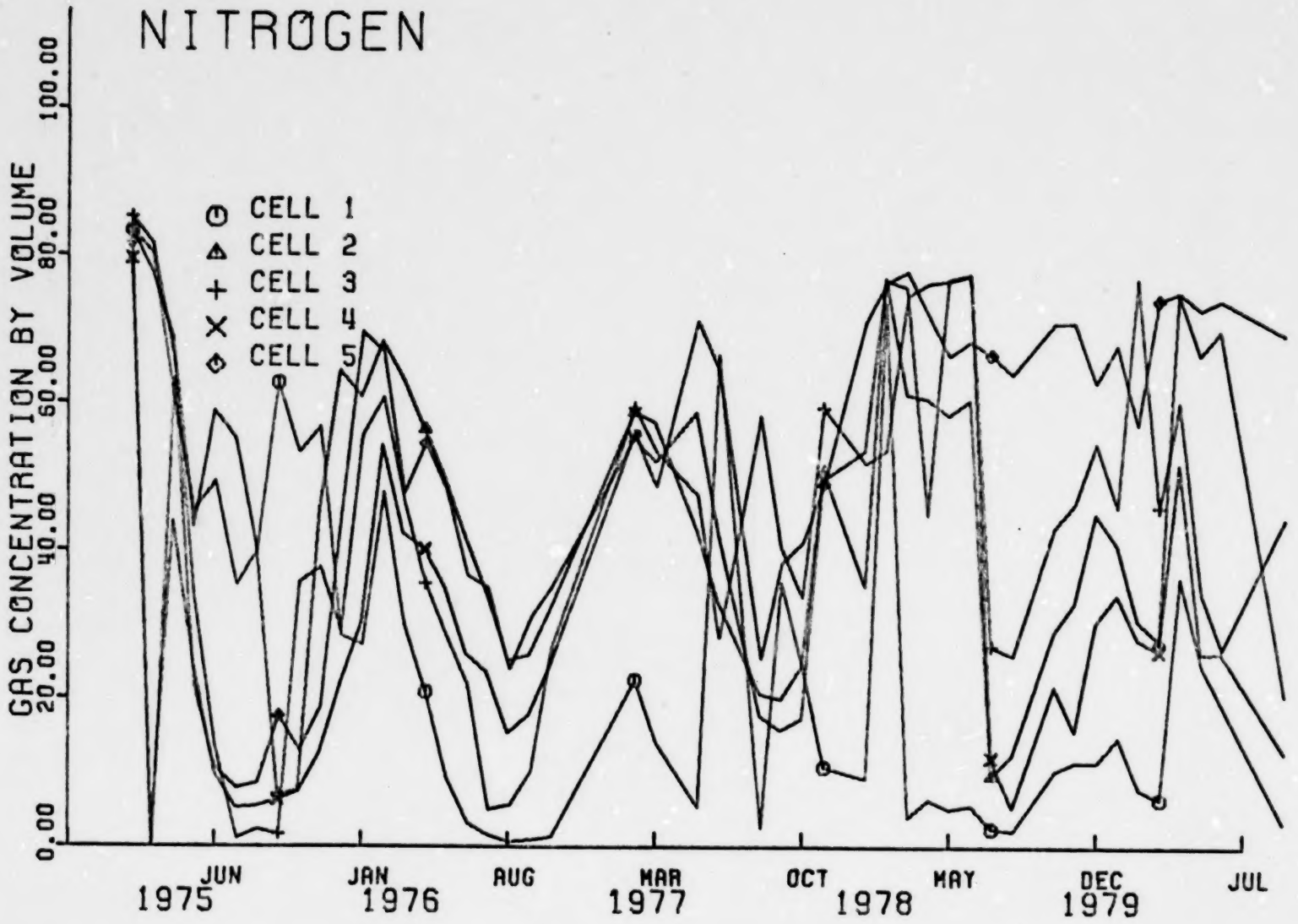

Figure 17. Nitrogen - percent composition vs. time.

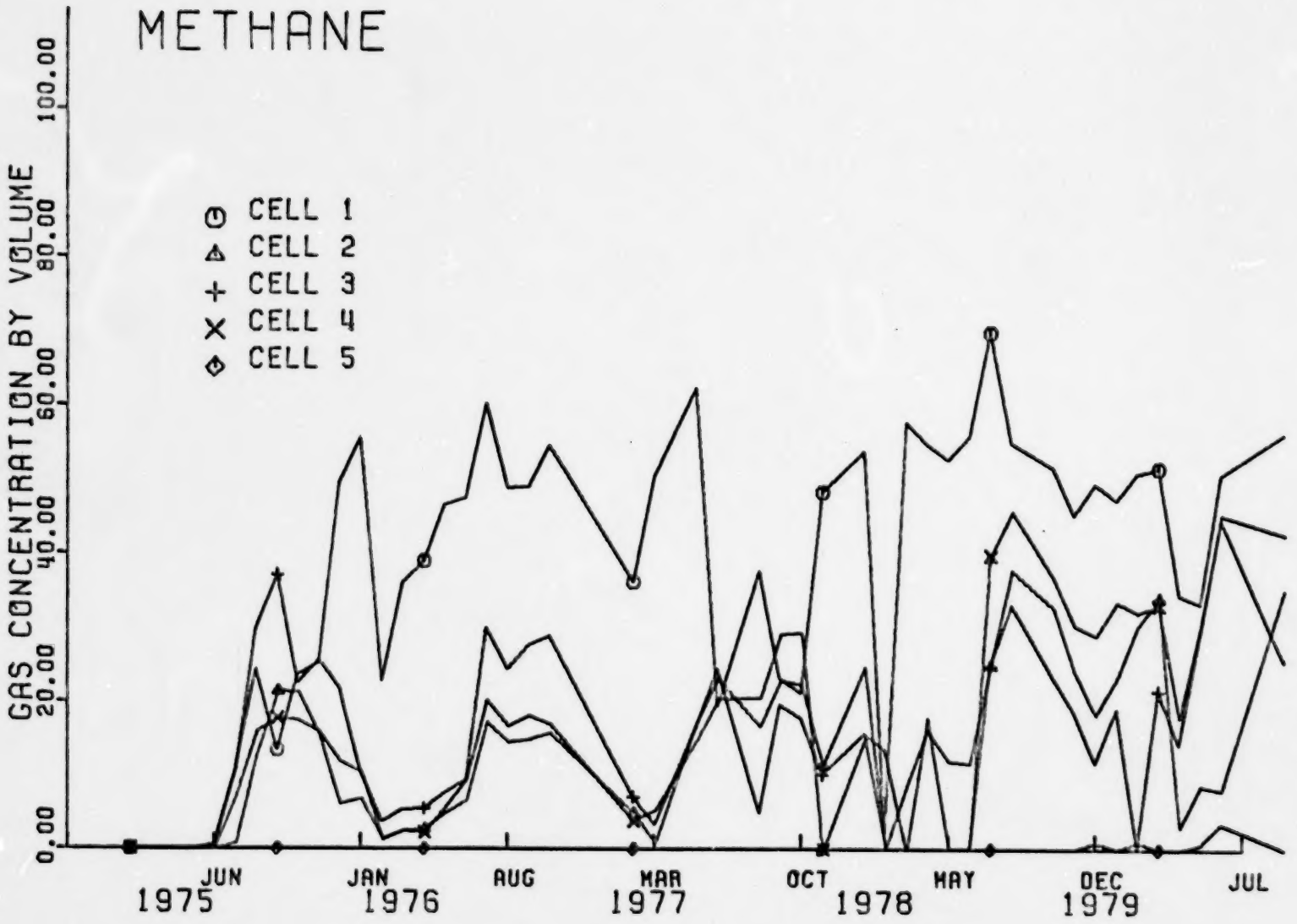

Figure 18. Methane - percent composition vs. time.

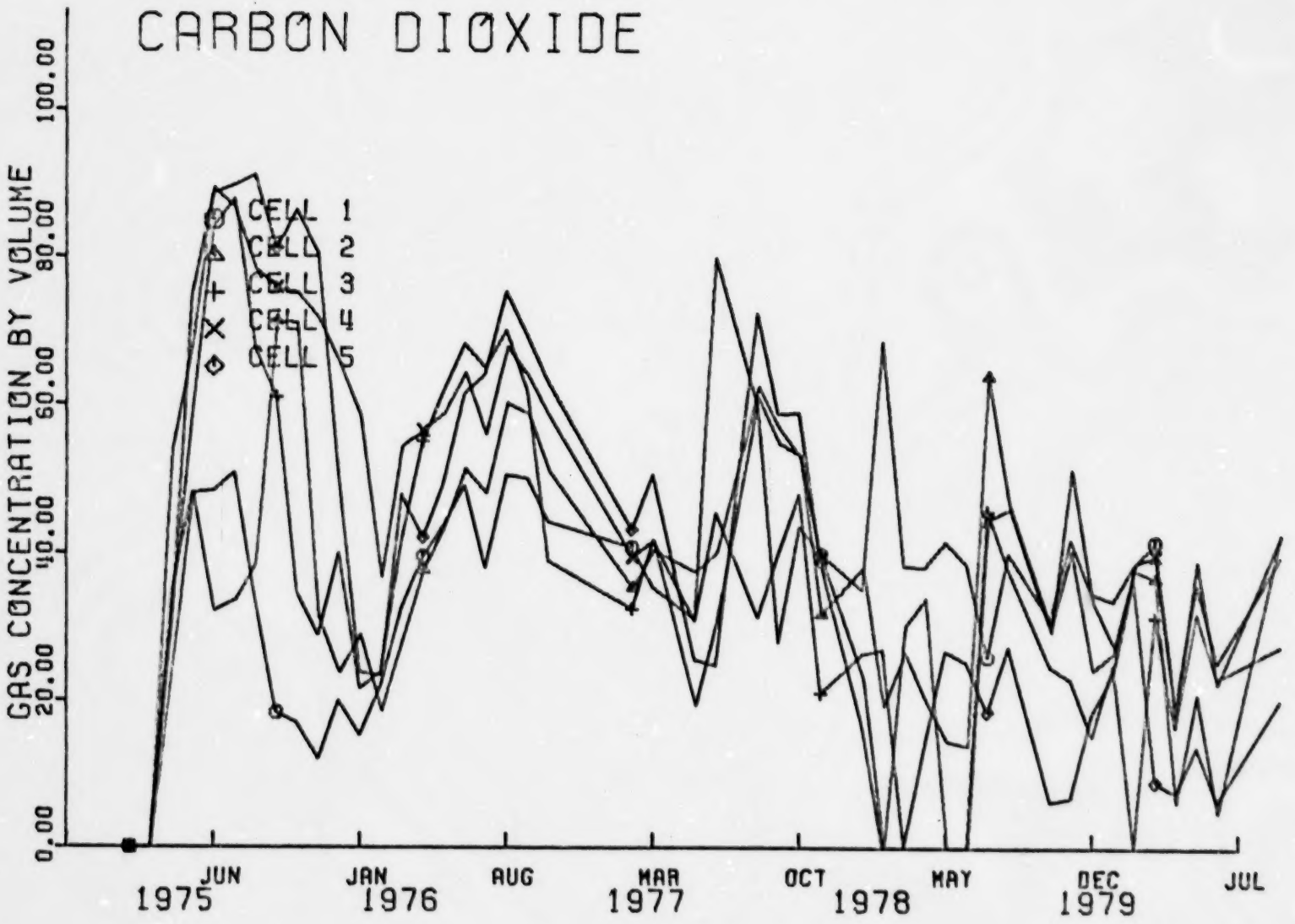

Figure 19. Carbon dioxide - percent composition vs. time.

APPENDIX A

RAW LEACHATE COMPOSITION DATA*

* A zero in the data columns usually indicate that no data existed for that measurement.

TABLE A-1. LEACHATE VOLUME (liters)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	1.00	4.00	1.00	1.00	1.00
20175	0.00	15.10	83.30	0.00	0.00
30175	0.00	16.00	8.00	0.00	0.00
40175	0.00	356.00	210.00	87.90	0.00
50175	696.00	458.00	7.60	159.00	0.00
60175	318.00	326.00	8.00	117.00	6.00
70175	198.00	133.00	7.60	64.30	21.10
80175	1.20	38.30	8.00	64.80	17.50
90175	0.03	18.90	7.60	94.60	34.10
100175	3.00	29.50	7.60	26.50	18.90
110175	231.00	83.30	7.60	30.30	18.90
120175	304.00	183.00	1.08	75.90	72.50
10176	122.00	91.80	140.00	190.00	266.00
20176	402.00	387.00	140.00	187.00	209.00
30176	90.80	90.80	140.00	204.00	159.00
40176	626.00	591.00	1840.00	395.00	357.00
50176	716.00	656.00	626.00	262.00	542.00
60176	569.00	599.00	313.00	266.00	228.00
70176	318.00	327.00	138.00	274.00	194.00
80176	62.00	62.00	138.00	232.00	115.00
90176	0.50	31.00	141.00	190.00	92.00
100176	0.25	200.00	140.00	194.00	152.00
110176	327.00	247.00	208.00	213.00	183.00
120176	342.00	330.00	209.00	255.00	300.00
10177	10.00	47.00	757.00	189.00	190.00
20177	19.00	19.00	2.00	98.00	151.00
30177	284.00	322.00	435.00	246.00	189.00
40177	2.00	2.00	2.00	2.00	2.00
50177	0.00	0.00	0.00	0.00	0.00
60177	397.00	466.00	291.00	257.00	246.00
70177	511.00	426.00	2.00	483.00	388.00
80177	1.00	92.00	1.00	3.00	1.50
92077	43.00	50.00	2.00	5.00	16.00

(continued)

TABLE A-1. LEACHATE VOLUME (liters) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	35.00	43.00	474.00	20.00	27.00
112477	303.00	98.00	435.00	246.00	163.00
122177	210.00	178.00	647.00	151.00	182.00
11678	312.00	279.00	1.00	161.00	118.00
30178	72.00	48.00	114.00	91.00	53.00
32878	174.00	189.00	98.00	95.00	74.00
41778	613.00	632.00	322.00	303.00	208.00
52478	265.00	280.00	70.00	81.00	78.00
63078	246.00	265.00	3.00	83.00	22.00
72678	140.00	79.50	1.00	62.50	45.40
83178	78.00	65.00	59.00	40.00	11.00
92878	170.00	143.00	1.00	284.00	303.00
103178	3.00	42.00	628.00	211.00	192.00
112878	211.00	194.00	457.00	344.00	400.00
122778	254.00	238.00	408.00	193.00	147.00
13079	283.00	265.00	3.00	219.00	211.00
22779	41.00	30.00	382.00	223.00	174.00
32779	336.00	317.00	329.00	140.00	147.00
43079	510.00	475.00	798.00	370.00	419.00
53079	640.00	657.00	795.00	405.00	428.00
62879	474.00	534.00	417.00	205.00	220.00
73179	322.00	398.00	3.00	360.00	455.00
82979	100.00	100.00	3.00	119.00	157.00
93079	2.00	53.00	3.00	114.00	114.00
103179	19.00	38.00	398.00	182.00	227.00
113079	238.00	191.00	397.00	712.00	855.00
122779	8.00	256.00	396.00	405.00	479.00
13080	477.00	326.00	1.00	420.00	473.00
22880	8.00	40.00	396.00	174.00	114.00
32780	343.00	295.00	791.00	371.00	155.00
42880	487.00	577.00	791.00	755.00	776.00
52880	628.00	636.00	791.00	447.00	802.00
63080	625.00	587.00	397.00	458.00	367.00
73080	413.00	583.00	1.00	598.00	379.00

TABLE A-2. pH (standard units)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	5.70	6.40	6.40	5.70	5.80
20175	0.00	6.20	5.90	0.00	0.00
30175	0.00	5.85	5.90	0.00	0.00
40175	0.00	5.50	5.80	5.20	0.00
50175	5.40	5.40	5.85	5.30	0.00
60175	5.30	5.60	5.80	5.70	5.80
70175	5.26	5.67	5.70	5.61	5.88
80175	5.38	5.97	5.79	5.28	5.98
90175	0.00	5.80	5.70	5.20	5.80
100175	5.20	5.80	5.80	5.50	5.90
110175	5.15	5.60	5.80	5.40	5.90
120175	5.60	5.40	5.75	5.29	5.97
10176	5.40	5.60	5.80	5.25	6.00
20176	5.95	5.50	5.70	5.25	5.95
30176	6.05	6.01	6.30	5.80	6.22
40176	6.05	5.40	5.70	5.50	5.90
50176	5.40	5.50	5.70	5.60	5.90
60176	6.00	5.60	5.70	6.00	5.85
70176	6.30	5.75	5.80	6.10	6.15
80176	6.85	5.65	5.75	5.85	6.00
90176	7.00	6.00	6.00	6.00	6.00
100176	7.60	5.60	5.80	5.40	5.90
110176	7.10	5.40	5.60	5.50	6.00
120176	6.90	5.50	5.70	5.40	5.90
10177	6.80	5.40	5.80	5.40	5.80
20177	6.30	5.60	5.40	5.50	5.70
30177	7.80	6.30	6.50	5.90	6.60
40177	6.60	5.30	5.60	5.50	5.70
50177	0.00	0.00	0.00	0.00	0.00
60177	6.80	5.60	5.80	5.60	5.90
70177	6.70	5.48	5.82	5.60	5.80
80177	6.90	5.50	5.90	5.50	5.80
92077	7.20	5.55	5.90	5.60	5.85

(continued)

TABLE A-2. pH (standard units) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	6.10	4.90	5.00	4.75	5.00
112477	7.00	5.45	5.70	5.45	5.60
122177	7.00	5.45	5.70	5.45	5.60
11678	6.70	5.30	5.50	5.40	5.55
30178	6.95	5.70	5.60	5.00	5.60
32878	6.90	5.70	5.70	5.00	5.50
41778	6.90	5.60	5.60	5.50	5.60
52478	7.00	5.60	5.70	5.60	5.70
63078	6.90	5.75	5.85	5.70	5.95
72678	6.60	5.40	5.80	5.50	5.60
83178	7.10	5.50	5.80	5.40	5.70
92878	7.00	0.00	6.00	5.90	5.70
103178	6.60	0.00	5.60	5.30	5.40
112878	6.80	0.00	5.30	5.10	5.30
122778	6.60	5.50	5.60	5.80	5.80
13079	6.81	5.81	5.62	5.88	5.89
22779	6.84	5.73	5.67	5.71	5.73
32779	0.00	0.00	0.00	0.00	0.00
43079	7.25	5.70	5.25	5.91	5.61
53079	6.74	5.57	5.33	5.60	5.53
62879	6.69	5.40	5.39	5.56	5.57
73179	6.57	5.73	5.63	5.83	5.87
82979	6.82	6.06	5.60	5.64	5.65
93079	7.26	6.30	5.63	5.87	5.71
103179	6.93	6.70	5.57	5.81	5.74
113079	6.93	6.09	6.23	6.27	5.83
122779	6.87	6.30	5.73	6.10	5.69
13080	6.73	6.52	6.16	6.50	5.80
22880	6.85	6.81	6.26	6.60	5.82
32780	6.77	6.73	6.68	6.63	5.90
42880	6.96	5.60	6.48	6.40	5.78
52880	6.73	5.63	6.43	6.40	5.87
63080	6.78	5.94	6.60	6.45	5.84
73080	6.80	6.63	6.64	6.70	5.82

TABLE A-3. CHEMICAL OXYGEN DEMAND (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	455.00	783.00	957.00	164.00	197.00
20175	0.00	3290.00	5320.00	0.00	0.00
30175	0.00	6470.00	7350.00	0.00	0.00
40175	0.00	7780.00	8920.00	17700.00	0.00
50175	14700.00	9050.00	10400.00	21900.00	0.00
60175	18700.00	11200.00	13400.00	19600.00	0.00
70175	20600.00	12000.00	22300.00	21600.00	11400.00
80175	14100.00	10000.00	25300.00	27200.00	14800.00
90175	0.00	11400.00	26500.00	20100.00	15100.00
100175	21100.00	14300.00	33800.00	22700.00	20800.00
110175	24000.00	17000.00	25500.00	23000.00	20900.00
120175	16600.00	20000.00	26000.00	21600.00	23800.00
10176	17800.00	13800.00	29700.00	29400.00	14600.00
20176	11100.00	13700.00	26700.00	29800.00	21400.00
30176	14500.00	16000.00	31300.00	40400.00	20300.00
40176	14700.00	19600.00	32400.00	47200.00	26900.00
50176	14700.00	16100.00	31200.00	51300.00	26300.00
60176	9630.00	18600.00	26900.00	63400.00	22100.00
70176	11900.00	22800.00	28400.00	51500.00	23700.00
80176	6180.00	19400.00	28700.00	58800.00	28100.00
90176	2350.00	17200.00	23100.00	58500.00	27800.00
100176	1070.00	21400.00	26100.00	88700.00	29500.00
110176	1460.00	19700.00	27200.00	65000.00	26600.00
120176	1260.00	16000.00	29000.00	61500.00	30900.00
10177	1100.00	16500.00	29000.00	56500.00	25700.00
20177	1580.00	17100.00	25900.00	48600.00	30700.00
30177	1840.00	15300.00	28900.00	32100.00	26000.00
40177	4550.00	18700.00	24700.00	20500.00	29600.00
50177	0.00	0.00	0.00	0.00	16500.00
60177	1430.00	24100.00	28500.00	26700.00	0.00
70177	941.00	20800.00	28500.00	34100.00	31800.00
80177	1470.00	21900.00	28900.00	37200.00	31700.00
92077	854.00	17800.00	22200.00	32800.00	28000.00
					24700.00

(continued)

TABLE A-3. CHEMICAL OXYGEN DEMAND (mg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	813.00	14700.00	25200.00	32200.00	28000.00
112477	859.00	21800.00	25300.00	32000.00	29400.00
122177	1110.00	7210.00	27900.00	43600.00	29600.00
11678	845.00	13400.00	26400.00	38000.00	31700.00
30178	812.00	15000.00	24800.00	35300.00	30800.00
32878	456.00	9890.00	24300.00	30400.00	28500.00
41778	428,00	19800.00	22200.00	24200.00	30100.00
52478	589.00	17600.00	16600.00	20500.00	22800.00
63078	886.00	19500.00	22000.00	30200.00	28600.00
72678	1180.00	18000.00	22700.00	33000.00	29200.00
83178	1500.00	21000.00	24000.00	31500.00	27000.00
92878	525.00	16200.00	26000.00	45000.00	28000.00
103178	520.00	16200.00	31000.00	40000.00	27000.00
112878	4000.00	16200.00	19000.00	38000.00	26000.00
122778	970.00	15000.00	25000.00	34000.00	32000.00
13079	600.00	55000.00	43000.00	65000.00	53000.00
22779	683.00	18500.00	13100.00	17400.00	17600.00
32779	360.00	2100.00	5230.00	15300.00	4300.00
43079	1460.00	11500.00	8500.00	18500.00	14500.00
53079	1560.00	6900.00	6100.00	10100.00	5100.00
62879	656.00	6830.00	9000.00	12000.00	14300.00
73179	3330.00	7500.00	8750.00	14000.00	16600.00
82979	660.00	7600.00	12700.00	21800.00	16200.00
93079	120.00	5880.00	10800.00	19900.00	17300.00
103179	610.00	3200.00	11200.00	13600.00	13000.00
113079	688.00	8080.00	7480.00	16400.00	9000.00
122779	790.00	5850.00	10400.00	7550.00	14100.00
13080	560.00	4650.00	11500.00	11100.00	10600.00
22880	720.00	1830.00	5750.00	8650.00	12800.00
32780	678.00	1900.00	2050.00	9750.00	11200.00
42880	1340.00	13000.00	2410.00	11000.00	10100.00
52880	1320.00	12800.00	2650.00	10500.00	5960.00
63080	1970.00	11600.00	1730.00	5730.00	6340.00
73080	708.00	3350.00	925.00	5100.00	7650.00

TABLE A-4. TOTAL ORGANIC CARBON (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	74.00	360.00	410.00	60.00	56.00
20175	0.00	880.00	1550.00	0.00	0.00
30175	0.00	1800.00	1800.00	0.00	0.00
40175	0.00	3550.00	3300.00	7600.00	0.00
50175	5800.00	3700.00	3700.00	8100.00	0.00
60175	7300.00	4000.00	4200.00	7600.00	5300.00
70175	5750.00	3650.00	5800.00	7200.00	4250.00
80175	7000.00	5300.00	8600.00	9000.00	5500.00
90175	0.00	4300.00	6500.00	9200.00	8600.00
100175	9000.00	6000.00	10000.00	8500.00	8000.00
110175	7400.00	4850.00	8300.00	7000.00	5000.00
120175	5200.00	4700.00	6100.00	6500.00	4100.00
10176	5200.00	4700.00	6100.00	6500.00	4100.00
20176	4300.00	5900.00	10400.00	14200.00	7600.00
30176	6300.00	7800.00	11400.00	16000.00	12700.00
40176	6600.00	8400.00	12600.00	18000.00	12600.00
50176	7800.00	7800.00	11400.00	22200.00	9600.00
60176	6000.00	8400.00	11400.00	22200.00	10200.00
70176	3600.00	9600.00	12000.00	23400.00	10800.00
80176	3200.00	6800.00	10000.00	21200.00	10300.00
90176	1600.00	8000.00	9600.00	20400.00	10000.00
100176	4000.00	7600.00	9600.00	20400.00	11000.00
110176	4400.00	6800.00	9600.00	17000.00	27600.00
120176	1800.00	7800.00	11400.00	23400.00	12600.00
10177	1800.00	7800.00	12000.00	22800.00	12600.00
20177	3600.00	7800.00	12600.00	22800.00	12000.00
30177	4000.00	7800.00	12000.00	25000.00	12800.00
40177	8000.00	10400.00	10400.00	20400.00	11200.00
50177	0.00	0.00	0.00	0.00	0.00
60177	14000.00	9600.00	10400.00	10800.00	17600.00
70177	4800.00	15200.00	13600.00	16800.00	10100.00
80177	12800.00	5200.00	14800.00	14800.00	10400.00
92077	1600.00	9200.00	10800.00	15200.00	11200.00

(continued)

TABLE A-4. TOTAL ORGANIC CARBON (mg/ℓ)(continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	2000.00	9200.00	10800.00	16000.00	12800.00
112477	4800.00	8000.00	9200.00	16800.00	11200.00
122177	2800.00	7400.00	9200.00	16000.00	10800.00
11678	1600.00	10800.00	8800.00	13600.00	10800.00
30178	400.00	14800.00	10400.00	13600.00	11200.00
32878	480.00	6600.00	10000.00	12400.00	12800.00
41778	440.00	0.00	8800.00	12400.00	11200.00
52478	4000.00	7200.00	7600.00	11700.00	10800.00
63078	4000.00	8000.00	0.00	12400.00	9600.00
72678	540.00	8400.00	9600.00	15200.00	11600.00
83178	940.00	12000.00	13200.00	20400.00	13200.00
92878	1120.00	8030.00	10400.00	17600.00	9600.00
103178	1200.00	8030.00	11200.00	22000.00	12000.00
112878	1080.00	8030.00	10400.00	21200.00	15200.00
122778	3200.00	8000.00	9000.00	11200.00	9600.00
13079	6400.00	10800.00	17600.00	30000.00	18800.00
22779	800.00	8030.00	3200.00	12800.00	8000.00
32779	200.00	4800.00	4400.00	7200.00	5200.00
43079	700.00	8030.00	7200.00	12800.00	10000.00
53079	4800.00	8600.00	8000.00	13200.00	13200.00
62879	460.00	6400.00	8800.00	12800.00	9600.00
73179	2000.00	5200.00	8000.00	12400.00	10800.00
82979	295.00	4400.00	6300.00	24000.00	7000.00
93079	480.00	4400.00	8000.00	10400.00	7600.00
103179	260.00	3200.00	6400.00	10800.00	7600.00
113079	360.00	3600.00	4400.00	6800.00	7200.00
122779	250.00	1900.00	3200.00	4400.00	4600.00
13080	720.00	7200.00	6800.00	16800.00	20400.00
22880	280.00	800.00	1600.00	3200.00	4000.00
32780	160.00	700.00	580.00	2800.00	3200.00
42880	410.00	4500.00	1000.00	3000.00	3100.00
52880	320.00	3900.00	740.00	3200.00	1500.00
63080	690.00	3900.00	480.00	2000.00	2000.00
73080	0.00	0.00	0.00	0.00	0.00

TABLE A-5. TOTAL ALKALINITY (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	0.00	0.00	0.00	0.00
20175	0.00	2820.00	3120.00	0.00	0.00
30175	0.00	2580.00	2930.00	0.00	0.00
40175	2700.00	2930.00	2940.00	5920.00	0.00
50175	4580.00	2800.00	3040.00	4.12	0.00
60175	7600.00	1800.00	4580.00	7000.00	4800.00
70175	0.00	0.00	0.00	0.00	0.00
80175	0.00	0.00	0.00	0.00	0.00
90175	0.00	0.00	0.00	0.00	0.00
100175	10400.00	7400.00	11800.00	12000.00	8400.00
110175	8600.00	6400.00	9900.00	9600.00	7400.00
120175	0.00	0.00	0.00	0.00	0.00
10176	0.00	0.00	0.00	0.00	0.00
20176	5900.00	4500.00	10000.00	12400.00	8500.00
30176	5200.00	5800.00	10000.00	13400.00	6000.00
40176	7120.00	5670.00	10400.00	17200.00	6910.00
50176	6600.00	6200.00	9800.00	16100.00	6600.00
60176	4600.00	5400.00	8600.00	20200.00	7800.00
70176	5000.00	5600.00	8600.00	20600.00	7400.00
80176	4000.00	5700.00	8500.00	18400.00	7300.00
90176	3700.00	6700.00	9000.00	17200.00	8300.00
100176	2700.00	6900.00	9000.00	19300.00	7600.00
110176	2800.00	6100.00	8400.00	20400.00	8100.00
120176	0.00	0.00	0.00	0.00	0.00
10177	0.00	0.00	0.00	0.00	0.00
20177	3200.00	6500.00	9500.00	18300.00	7600.00
30177	3100.00	5800.00	10100.00	14800.00	9300.00
40177	4660.00	6260.00	9760.00	11600.00	7760.00
50177	0.00	0.00	0.00	0.00	0.00
60177	5200.00	7150.00	9700.00	10200.00	10600.00
70177	3300.00	6900.00	9700.00	13000.00	9100.00
80177	2300.00	8300.00	7200.00	10500.00	5800.00
92077	3450.00	8900.00	8800.00	17400.00	9900.00

(continued)

TABLE A-5. TOTAL ALKALINITY (mg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	0.00	0.00	0.00	0.00	0.00
112477	5750.00	10800.00	12200.00	16700.00	11900.00
122177	2860.00	4260.00	7660.00	15600.00	8060.00
11678	1100.00	3000.00	6800.00	13800.00	7600.00
30178	3000.00	5400.00	8100.00	13600.00	8800.00
32878	2400.00	4800.00	8200.00	10800.00	7800.00
41778	2300.00	4900.00	7600.00	10000.00	7700.00
52478	2300.00	5750.00	8100.00	11100.00	8900.00
63078	2500.00	5700.00	6900.00	11600.00	7700.00
72678	1900.00	4680.00	6360.00	13100.00	7700.00
83178	3350.00	6590.00	7820.00	14600.00	8150.00
92878	3260.00	5430.00	1400.00	8700.00	2220.00
103178	4220.00	5430.00	3900.00	7860.00	3900.00
112878	1460.00	5430.00	760.00	5360.00	2700.00
122778	2720.00	3260.00	4870.00	12100.00	7500.00
13079	3730.00	5970.00	5200.00	14500.00	7130.00
22779	3570.00	8060.00	6070.00	18700.00	8660.00
32779	2320.00	7630.00	4130.00	14800.00	7710.00
43079	3250.00	5730.00	4180.00	11000.00	6060.00
53079	2630.00	5290.00	3480.00	7990.00	5570.00
62879	2530.00	3120.00	3760.00	7700.00	5200.00
73179	2680.00	3950.00	4490.00	10200.00	5600.00
82979	2880.00	3930.00	4340.00	10700.00	5020.00
93079	2960.00	4210.00	4460.00	9470.00	4630.00
103179	2970.00	3910.00	4240.00	9930.00	4400.00
113079	3560.00	3980.00	3430.00	9040.00	5120.00
122779	3500.00	3200.00	4060.00	6680.00	4800.00
13080	2210.00	2610.00	3530.00	5760.00	3680.00
22880	2370.00	3110.00	2530.00	5480.00	3690.00
32780	2220.00	2240.00	2390.00	5540.00	3590.00
42880	2490.00	4250.00	2220.00	4900.00	2630.00
52880	2330.00	3610.00	1920.00	4810.00	1420.00
63080	2610.00	3690.00	1550.00	2830.00	1580.00
73080	2410.00	2720.00	1900.00	3820.00	2170.00

TABLE A-6. TOTAL KJELDAHL NITROGEN (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	0.00	0.00	0.00	0.00
20175	0.00	9.50	112.00	0.00	0.00
30175	0.00	22.40	58.20	0.00	0.00
40175	0.00	78.40	89.60	146.00	0.00
50175	204.00	155.00	116.00	317.00	0.00
60175	235.00	168.00	213.00	325.00	213.00
70175	0.00	0.00	0.00	0.00	0.00
80175	0.00	0.00	0.00	0.00	0.00
90175	0.00	0.00	0.00	0.00	0.00
100175	381.00	213.00	482.00	448.00	426.00
110175	392.00	224.00	406.00	398.00	364.00
120175	0.00	0.00	0.00	0.00	0.00
10176	0.00	0.00	0.00	0.00	0.00
20176	0.00	0.00	0.00	0.00	0.00
30176	0.00	0.00	0.00	0.00	0.00
40176	287.00	392.00	532.00	896.00	497.00
50176	308.00	343.00	532.00	1150.00	504.00
60176	137.00	280.00	396.00	1290.00	441.00
70176	182.00	399.00	455.00	1390.00	567.00
80176	252.00	364.00	483.00	1440.00	560.00
90176	0.00	0.00	0.00	0.00	0.00
100176	322.00	364.00	434.00	1320.00	511.00
110176	315.00	343.00	525.00	1290.00	623.00
120176	0.00	0.00	0.00	0.00	0.00
10177	0.00	0.00	0.00	0.00	0.00
20177	210.00	322.00	525.00	1120.00	637.00
30177	168.00	252.00	525.00	658.00	651.00
40177	150.00	353.00	336.00	252.00	1080.00
50177	0.00	0.00	0.00	0.00	0.00
60177	187.00	477.00	514.00	505.00	682.00
70177	176.00	487.00	519.00	665.00	716.00
80177	202.00	442.00	470.00	637.00	494.00
92077	302.00	400.00	504.00	644.00	602.00

(continued)

TABLE A-6. TOTAL KJELDAHL NITROGEN (mg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	343.00	434.00	518.00	742.00	630.00
112477	221.00	378.00	448.00	665.00	567.00
122177	182.00	228.00	455.00	770.00	496.00
11678	160.00	219.00	476.00	770.00	1390.00
30178	162.00	266.00	105.00	518.00	686.00
32878	137.00	193.00	448.00	672.00	678.00
41778	98.00	417.00	483.00	784.00	672.00
52478	165.00	454.00	420.00	417.00	592.00
63078	220.00	434.00	442.00	570.00	508.00
72678	283.00	454.00	497.00	721.00	693.00
83178	331.00	641.00	552.00	861.00	737.00
92878	108.00	345.00	393.00	9.00	147.00
103178	308.00	345.00	417.00	871.00	554.00
112878	208.00	345.00	307.00	658.00	437.00
122778	84.00	349.00	267.00	496.00	432.00
13079	109.00	264.00	288.00	612.00	516.00
22779	150.00	345.00	211.00	586.00	463.00
32779	86.00	257.00	200.00	329.00	371.00
43079	91.00	345.00	205.00	369.00	430.00
53079	160.00	343.00	389.00	252.00	370.00
62879	59.00	190.00	160.00	190.00	270.00
73179	148.00	263.00	244.00	388.00	434.00
82979	249.00	286.00	235.00	451.00	446.00
93079	280.00	197.00	355.00	352.00	300.00
103179	260.00	319.00	213.00	379.00	374.00
113079	165.00	212.00	143.00	287.00	248.00
122779	178.00	190.00	295.00	251.00	290.00
13080	94.00	194.00	192.00	283.00	300.00
22880	185.00	167.00	163.00	340.00	348.00
32780	147.00	156.00	256.00	354.00	301.00
42880	193.00	303.00	139.00	233.00	171.00
52880	136.00	327.00	140.00	273.00	117.00
63080	146.00	330.00	125.00	158.00	117.00
73080	115.00	226.00	130.00	188.00	146.00

TABLE A-7. TOTAL SOLIDS (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	0.00	0.00	0.00	0.00
20175	0.00	4100.00	5300.00	0.00	0.00
30175	0.00	5300.00	5900.00	0.00	0.00
40175	0.00	8100.00	8000.00	22700.00	0.00
50175	14500.00	7800.00	6900.00	21000.00	0.00
60175	16700.00	8300.00	3500.00	19800.00	12500.00
70175	14900.00	7010.00	14200.00	20500.00	12300.00
80175	11000.00	7920.00	15800.00	18300.00	10900.00
90175	14500.00	9000.00	17000.00	19000.00	14000.00
100175	18000.00	18000.00	19000.00	18000.00	14400.00
110175	16200.00	10800.00	19000.00	16000.00	14500.00
120175	15200.00	11200.00	16600.00	18400.00	14400.00
10176	12500.00	10500.00	20800.00	23100.00	15600.00
20176	11300.00	10400.00	21400.00	25500.00	15900.00
30176	11100.00	10800.00	20600.00	27300.00	15200.00
40176	12500.00	11900.00	20000.00	33100.00	15500.00
50176	13000.00	12200.00	19300.00	46000.00	14800.00
60176	8930.00	12200.00	18700.00	50900.00	16400.00
70176	10400.00	13200.00	18500.00	49900.00	18000.00
80176	7560.00	12400.00	18200.00	49200.00	16700.00
90176	6350.00	13700.00	18000.00	46900.00	19500.00
100176	3700.00	13800.00	18100.00	45500.00	17500.00
110176	3930.00	11700.00	18000.00	48100.00	27100.00
120176	4200.00	12000.00	18400.00	48300.00	17300.00
10177	4410.00	10800.00	17900.00	46100.00	20600.00
20177	3920.00	11800.00	17600.00	40100.00	17800.00
30177	3840.00	9750.00	18500.00	26600.00	19100.00
40177	8560.00	12100.00	16700.00	21500.00	17200.00
50177	0.00	0.00	0.00	0.00	0.00
60177	3540.00	13200.00	18100.00	20500.00	18400.00
70177	4090.00	12600.00	16900.00	24500.00	20100.00
80177	4890.00	14800.00	17700.00	25000.00	15000.00
92077	4850.00	14600.00	16700.00	28300.00	20200.00

(continued)

TABLE A-7. TOTAL SOLIDS (mg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	4520.00	15000.00	16300.00	27000.00	18100.00
112477	4080.00	14600.00	15600.00	28400.00	18100.00
122177	4230.00	5760.00	15800.00	39400.00	18400.00
11678	3390.00	7800.00	17700.00	29300.00	19400.00
30178	4050.00	8910.00	17000.00	25400.00	20200.00
32878	2690.00	6240.00	13700.00	21000.00	19400.00
41778	3160.00	11600.00	14800.00	19500.00	17200.00
52478	3340.00	12800.00	14300.00	20600.00	18900.00
63078	4490.00	13900.00	0.00	25100.00	19900.00
72678	5100.00	12400.00	14900.00	27000.00	19100.00
83178	4600.00	13800.00	14600.00	27700.00	20000.00
92878	4620.00	9990.00	12900.00	30000.00	17700.00
103178	5070.00	9990.00	14300.00	32100.00	14000.00
112878	4070.00	9990.00	9720.00	27200.00	16600.00
122778	3750.00	5910.00	9230.00	21000.00	15400.00
13079	3380.00	8540.00	8380.00	25100.00	15100.00
22779	3220.00	11800.00	9180.00	26800.00	14800.00
32779	2500.00	11800.00	6220.00	22900.00	14400.00
43079	4180.00	9760.00	7230.00	19400.00	13700.00
53079	4250.00	11000.00	7430.00	16200.00	13500.00
62879	3940.00	7740.00	8020.00	16500.00	13300.00
73179	3730.00	7190.00	8780.00	19300.00	12700.00
82979	4050.00	7780.00	10700.00	22500.00	14600.00
93079	3780.00	7880.00	8780.00	19000.00	11300.00
103179	3710.00	6440.00	8380.00	19900.00	10500.00
113079	3580.00	6410.00	5620.00	14800.00	9850.00
122779	3530.00	4920.00	6360.00	12700.00	10200.00
13080	2940.00	5000.00	7600.00	12200.00	11300.00
22880	3950.00	4360.00	5360.00	11100.00	9560.00
32780	3050.00	3690.00	4040.00	11200.00	8700.00
42880	3700.00	9250.00	3920.00	9530.00	6340.00
52880	3880.00	8410.00	3440.00	10200.00	3600.00
63080	3890.00	7820.00	2570.00	5850.00	3770.00
73080	3110.00	4450.00	2440.00	6480.00	4950.00

TABLE A-8. IRON (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	14.00	50.00	0.50	0.30
20175	0.00	560.00	180.00	0.00	0.00
30175	0.00	75.00	100.00	0.00	0.00
40175	0.00	125.00	125.00	225.00	0.00
50175	150.00	200.00	175.00	300.00	0.00
60175	198.00	304.00	520.00	264.00	47.50
70175	260.00	395.00	675.00	415.00	80.00
80175	295.00	412.00	646.00	488.00	74.60
90175	366.00	386.00	438.00	482.00	97.00
100175	437.00	615.00	752.00	472.00	151.00
110175	461.00	423.00	714.00	497.00	151.00
120175	335.00	525.00	800.00	545.00	135.00
10176	358.00	545.00	400.00	525.00	135.00
20176	325.00	550.00	1100.00	920.00	175.00
30176	600.00	600.00	100.00	1000.00	200.00
40176	500.00	450.00	110.00	1400.00	183.00
50176	500.00	540.00	120.00	1300.00	250.00
60176	350.00	700.00	900.00	1400.00	112.00
70176	360.00	680.00	850.00	1500.00	120.00
80176	340.00	650.00	900.00	1300.00	110.00
90176	300.00	750.00	850.00	1350.00	100.00
100176	330.00	700.00	800.00	1300.00	115.00
110176	350.00	650.00	850.00	1330.00	100.00
120176	360.00	700.00	870.00	1300.00	105.00
10177	100.00	420.00	1210.00	1480.00	180.00
20177	40.00	740.00	880.00	1200.00	220.00
30177	90.00	620.00	1040.00	1240.00	280.00
40177	90.00	660.00	1000.00	1340.00	260.00
50177	0.00	0.00	0.00	0.00	0.00
60177	120.00	820.00	1100.00	1400.00	320.00
70177	100.00	780.00	1120.00	1300.00	380.00
80177	100.00	740.00	1020.00	1360.00	280.00
92077	6.50	754.00	1080.00	1340.00	351.00

(continued)

TABLE 8-A. IRON (mg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	30.00	670.00	930.00	1340.00	255.00
112477	45.00	650.00	850.00	1340.00	235.00
122177	55.00	435.00	810.00	1380.00	210.00
11678	50.00	375.00	736.00	1420.00	250.00
30178	43.00	223.00	770.00	1340.00	245.00
32878	90.00	350.00	700.00	1260.00	250.00
41778	50.00	360.00	620.00	1160.00	190.00
52478	14.00	340.00	520.00	900.00	220.00
63078	53.00	601.00	849.00	1520.00	283.00
72678	42.00	891.00	968.00	1410.00	493.00
83178	22.00	80.00	400.00	1670.00	179.00
92878	21.00	454.00	792.00	1460.00	383.00
103178	18.90	454.00	1020.00	1850.00	260.00
112878	29.80	454.00	378.00	1330.00	2330.00
122778	37.00	240.00	425.00	2210.00	209.00
13079	68.90	422.00	469.00	1770.00	320.00
22779	60.80	348.00	5670.00	2430.00	306.00
32779	120.00	548.00	1770.00	411.00	316.00
43079	148.00	665.00	771.00	2160.00	366.00
53079	86.00	712.00	845.00	1490.00	290.00
62879	65.30	294.00	541.00	1820.00	401.00
73179	37.60	339.00	633.00	1750.00	264.00
82979	23.20	385.00	660.00	1880.00	271.00
93079	31.30	350.00	795.00	1750.00	308.00
103179	28.50	256.00	844.00	1990.00	344.00
113079	39.20	307.00	459.00	1080.00	316.00
122779	51.50	239.00	356.00	670.00	284.00
13080	74.60	216.00	468.00	531.00	246.00
22880	54.80	159.00	422.00	472.00	266.00
32780	74.40	178.00	275.00	613.00	300.00
42880	96.60	456.00	314.00	600.00	224.00
52880	117.00	471.00	312.00	2010.00	149.00
63080	94.00	301.00	216.00	457.00	130.00
73080	111.00	144.00	143.00	400.00	170.00

TABLE A-9. COPPER (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	1.00	1.00	1.00	1.00
20175	0.00	1.00	0.00	0.00	0.00
30175	0.00	0.01	0.02	0.00	0.00
40175	0.00	0.03	0.01	0.05	0.00
50175	0.01	0.05	0.02	0.01	0.00
60175	0.08	0.05	0.10	0.05	0.05
70175	0.11	0.05	0.07	0.05	0.05
80175	0.05	0.05	0.09	0.12	0.05
90175	0.00	0.02	0.05	0.04	0.03
100175	0.05	0.04	0.07	0.05	0.05
110175	0.04	0.03	0.06	0.04	0.04
120175	0.20	0.05	0.20	0.05	0.05
10176	0.00	0.05	0.00	0.05	0.05
20176	0.00	0.06	0.13	0.06	0.00
30176	0.06	0.06	0.13	0.13	0.06
40176	0.03	0.00	0.09	0.12	0.08
50176	0.02	0.01	0.10	0.11	0.08
60176	0.01	0.02	0.07	0.07	0.17
70176	0.00	0.04	0.22	0.09	0.04
80176	0.08	0.10	0.13	0.15	0.21
90176	0.00	0.03	0.05	0.13	0.03
100176	0.00	0.03	0.03	0.10	0.03
110176	0.00	0.00	0.00	0.00	0.00
120176	0.00	0.00	0.00	0.00	0.00
10177	0.00	0.00	0.00	0.00	0.00
20177	0.00	0.00	0.00	0.00	0.00
30177	0.00	0.00	0.00	0.00	0.00
40177	0.00	0.00	0.00	0.00	0.00
50177	0.00	0.00	0.00	0.00	0.00
60177	0.06	0.06	0.13	0.13	0.06
70177	0.00	0.00	0.06	0.07	0.10
80177	0.03	0.04	0.04	0.12	0.03
92077	0.00	0.05	0.05	0.05	0.05

(continued)

TABLE A-9. COPPER (mg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	0.00	0.00	0.00	0.00	0.00
112477	0.00	0.00	0.00	0.00	0.00
122177	0.00	0.00	0.00	0.00	0.00
11678	0.00	0.00	0.00	0.00	0.00
30178	0.00	0.00	0.00	0.00	0.00
32878	0.00	0.00	0.00	0.00	0.00
41778	0.00	0.00	0.00	0.00	0.00
52478	0.02	0.11	0.08	0.06	0.14
63078	0.04	0.07	0.04	0.04	0.09
72678	0.07	0.09	0.07	0.07	0.07
83178	0.05	0.10	0.06	0.06	0.10
92878	0.02	0.07	0.08	0.05	0.04
103178	0.04	0.07	0.09	0.14	0.08
112878	0.03	0.07	0.03	0.08	0.05
122778	0.01	0.03	0.04	0.09	0.04
13079	0.02	0.04	0.04	0.08	0.06
22779	0.07	0.09	0.06	0.11	0.05
32779	0.02	0.02	0.02	0.07	0.02
43079	0.03	0.10	0.09	0.15	0.14
53079	0.03	0.10	0.07	0.12	0.11
62879	0.03	0.08	0.07	0.12	0.11
73179	0.02	0.03	0.04	0.10	0.08
82979	0.00	0.02	0.03	0.08	0.05
93079	0.06	0.06	0.00	0.06	0.04
103179	0.00	0.02	0.02	0.09	0.03
113079	0.00	0.00	0.00	0.03	0.02
122779	0.03	0.02	0.04	0.04	0.03
13080	0.00	0.01	0.03	0.02	0.02
22880	0.02	0.02	0.04	0.05	0.04
32780	0.02	0.02	0.03	0.03	0.03
42880	0.06	0.03	0.04	0.03	0.02
52880	0.01	0.02	0.03	0.03	0.02
63080	0.04	0.05	0.04	0.03	0.02
73080	0.02	0.02	0.02	0.01	0.01

(continued)

TABLE A-10. ZINC (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	0.42	0.20	0.22	0.14
20175	0.00	0.08	0.96	0.00	0.00
30175	0.00	12.50	0.80	0.00	0.00
40175	0.00	25.00	32.50	117.00	0.00
50175	15.10	29.00	42.50	103.00	0.00
60175	42.10	1.60	0.08	74.00	4.20
70175	60.00	7.20	1.20	95.00	10.00
80175	5.00	0.10	1.50	80.00	25.00
90175	0.00	0.84	0.68	86.30	27.50
100175	36.90	0.50	0.94	64.60	23.80
110175	54.10	0.38	0.66	70.30	30.10
120175	6.50	1.80	0.26	52.50	13.50
10176	13.50	1.20	0.20	47.00	17.50
20176	10.00	45.00	3.50	120.00	50.00
30176	7.00	1.20	0.50	120.00	50.00
40176	0.30	26.00	6.00	126.00	29.00
50176	5.00	4.00	0.40	50.00	2.90
60176	2.00	30.00	5.80	240.00	18.00
70176	10.00	40.00	5.00	200.00	10.00
80176	10.00	30.00	9.00	200.00	10.00
90176	5.00	10.00	5.00	200.00	50.00
100176	5.00	20.00	5.00	250.00	50.00
110176	10.00	50.00	10.00	200.00	10.00
120176	5.00	9.00	5.00	220.00	60.00
10177	10.00	7.00	1.00	210.00	56.00
20177	20.00	10.00	2.00	160.00	50.00
30177	26.00	11.00	10.00	148.00	34.00
40177	24.00	15.00	2.00	154.00	33.00
50177	0.00	0.00	0.00	0.00	0.00
60177	15.00	13.00	2.00	144.00	27.00
70177	8.00	11.00	1.00	154.00	34.00
80177	16.00	12.00	1.00	146.00	28.00
92077	1.70	23.10	0.00	172.00	16.50

(continued)

TABLE A-10. ZINC (mg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	10.50	25.50	10.50	242.00	41.50
112477	10.50	31.50	30.50	242.00	31.50
122177	10.50	14.50	10.50	222.00	30.50
11678	33.30	10.50	10.50	171.00	27.50
30178	27.50	10.00	11.50	152.00	36.00
32878	0.30	1.40	10.00	119.00	33.00
41778	0.30	22.00	15.00	105.00	30.00
52478	1.10	20.00	13.00	100.00	25.00
63078	1.60	20.80	13.80	126.00	21.20
72678	2.20	24.40	7.60	132.00	45.00
83178	0.46	6.12	1.02	64.40	22.90
92878	0.70	8.00	9.45	352.00	33.30
103178	0.55	8.00	3.45	167.00	22.00
112878	0.34	8.00	6.36	376.00	38.10
122778	1.21	5.12	6.10	196.00	31.10
13079	0.22	2.05	3.97	144.00	31.30
22779	0.08	5.34	4.27	181.00	36.80
32779	0.05	2.13	2.23	112.00	27.70
43079	0.21	5.31	3.93	152.00	34.00
53079	0.69	25.80	3.96	107.00	26.60
62879	0.31	3.38	2.22	131.00	25.60
73179	0.13	0.35	0.24	155.00	21.70
82979	0.09	0.16	0.15	135.00	21.00
93079	0.07	0.98	0.33	89.10	20.50
103179	0.07	0.12	0.20	117.00	21.10
113079	0.33	0.15	0.40	26.40	14.80
122779	0.21	0.18	0.40	22.90	13.80
13080	0.13	0.18	0.84	8.51	13.20
22880	0.11	0.08	0.51	5.86	13.80
32780	0.22	0.08	0.69	0.79	13.00
42880	0.32	2.31	0.52	0.51	8.55
52880	0.39	0.44	0.57	0.62	3.93
63080	0.37	2.73	0.38	0.32	2.75
73080	0.05	0.43	0.34	0.18	2.21

TABLE A-11. CADMIUM (µg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	500.00	500.00	500.00	500.00
20175	0.00	500.00	500.00	0.00	0.00
30175	0.00	20.00	20.00	0.00	0.00
40175	0.00	20.00	20.00	90.00	0.00
50175	10.00	10.00	20.00	50.00	0.00
60175	50.00	50.00	90.00	50.00	50.00
70175	50.00	50.00	70.00	50.00	50.00
80175	50.00	50.00	70.00	60.00	50.00
90175	0.00	51.00	86.00	90.00	68.00
100175	80.00	62.00	101.00	89.00	76.00
110175	77.00	50.00	74.00	66.00	56.00
120175	50.00	50.00	70.00	50.00	50.00
10176	0.00	0.00	30.00	50.00	0.00
20176	10.00	0.00	30.00	40.00	20.00
30176	0.00	0.00	20.00	40.00	10.00
40176	20.00	0.00	60.00	110.00	30.00
50176	50.00	50.00	50.00	100.00	0.00
60176	0.00	0.00	0.00	0.00	0.00
70176	0.00	20.00	80.00	110.00	180.00
80176	0.00	10.00	30.00	80.00	30.00
90176	10.00	30.00	20.00	100.00	30.00
100176	0.00	0.00	0.00	0.00	0.00
110176	0.00	0.00	0.00	0.00	0.00
120176	0.00	0.00	0.00	0.00	0.00
10177	20.00	60.00	80.00	120.00	80.00
20177	20.00	40.00	60.00	100.00	80.00
30177	30.00	60.00	60.00	110.00	80.00
40177	20.00	60.00	60.00	100.00	100.00
50177	0.00	0.00	0.00	0.00	0.00
60177	30.00	50.00	40.00	50.00	80.00
70177	20.00	60.00	50.00	80.00	60.00
80177	20.00	40.00	40.00	60.00	80.00
92077	0.00	0.00	0.00	0.00	0.00

(continued)

TABLE A-11. CADMIUM (µg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	0.00	0.00	0.00	0.00	0.00
112477	0.00	0.00	0.00	0.00	0.00
122177	0.00	0.00	0.00	0.00	0.00
11678	0.00	0.00	0.00	0.00	0.00
30178	0.00	0.00	0.00	0.00	0.00
32878	0.00	0.00	0.00	0.00	0.00
41778	20.00	30.00	20.00	30.00	50.00
52478	0.00	0.00	0.00	0.00	0.00
63078	0.00	0.00	0.00	0.00	0.00
72678	0.00	0.00	0.00	0.00	0.00
83178	0.00	0.00	0.00	0.00	0.00
92878	10.00	49.00	80.00	140.00	70.00
103178	30.00	49.00	80.00	170.00	80.00
112878	10.00	49.00	20.00	50.00	40.00
122778	20.00	30.00	40.00	90.00	70.00
13079	50.00	20.00	10.00	40.00	40.00
22779	20.00	40.00	50.00	80.00	70.00
32779	2.00	47.00	28.00	84.00	64.00
43079	15.50	30.50	25.00	64.90	49.80
53079	17.00	51.00	31.00	61.00	67.00
62879	15.00	32.00	31.00	64.00	54.00
73179	6.00	35.00	44.00	67.00	59.00
82979	4.00	26.00	29.00	76.00	46.00
93079	2.00	2.00	12.00	25.00	38.00
103179	2.00	2.00	21.00	67.00	56.00
113079	11.00	31.00	36.00	61.00	46.00
122779	6.00	6.00	14.00	36.00	35.00
13080	5.00	20.00	23.00	39.00	29.00
22880	1.00	12.00	15.00	29.00	27.00
32780	6.00	4.00	14.00	23.00	16.00
42880	18.00	36.00	16.00	39.00	32.00
52880	9.00	31.00	20.00	23.00	10.00
63080	5.00	23.00	8.00	15.00	10.00
73080	5.00	5.00	10.00	15.00	10.00

TABLE A-12. CHROMIUM (µg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	500.00	500.00	500.00	500.00
20175	0.00	500.00	500.00	0.00	0.00
30175	0.00	200.00	130.00	0.00	0.00
40175	0.00	500.00	270.00	1100.00	0.00
50175	120.00	350.00	190.00	420.00	0.00
60175	80.00	90.00	50.00	90.00	290.00
70175	400.00	200.00	300.00	500.00	400.00
80175	2500.00	200.00	400.00	500.00	400.00
90175	0.00	18.00	65.00	130.00	180.00
100175	108.00	320.00	170.00	90.00	170.00
110175	150.00	190.00	130.00	90.00	150.00
120175	200.00	200.00	125.00	125.00	200.00
10176	100.00	140.00	70.00	100.00	30.00
20176	0.00	50.00	50.00	50.00	50.00
30176	1030.00	0.00	50.00	50.00	50.00
40176	90.00	290.00	90.00	170.00	70.00
50176	700.00	500.00	1250.00	850.00	350.00
60176	200.00	200.00	100.00	500.00	200.00
70176	200.00	300.00	600.00	400.00	100.00
80176	100.00	300.00	100.00	300.00	100.00
90176	200.00	400.00	300.00	600.00	300.00
100176	120.00	360.00	370.00	530.00	270.00
110176	0.00	0.00	0.00	0.00	0.00
120176	0.00	100.00	100.00	200.00	100.00
10177	0.00	100.00	50.00	200.00	50.00
20177	0.00	0.00	100.00	100.00	0.00
30177	100.00	100.00	100.00	200.00	100.00
40177	0.00	100.00	100.00	150.00	0.00
50177	0.00	0.00	0.00	0.00	0.00
60177	0.00	150.00	0.00	100.00	100.00
70177	0.00	150.00	0.00	150.00	150.00
80177	0.00	100.00	0.00	100.00	0.00
92077	0.00	0.00	0.00	0.00	0.00

(continued)

TABLE A-12. CHROMIUM (µg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	0.00	0.00	0.00	0.00	0.00
112477	0.00	0.00	0.00	0.00	0.00
122177	0.00	0.00	0.00	0.00	0.00
11678	0.00	0.00	0.00	0.00	0.00
30178	30.00	30.00	50.00	40.00	40.00
32878	20.00	30.00	40.00	60.00	50.00
41778	0.00	520.00	0.00	20.00	20.00
52478	0.00	0.00	0.00	0.00	0.00
63078	0.00	140.00	0.00	30.00	20.00
72678	0.00	90.00	0.00	70.00	30.00
83178	0.00	0.00	0.00	0.00	0.00
92878	40.00	128.00	110.00	210.00	120.00
103178	30.00	128.00	70.00	170.00	60.00
112878	60.00	128.00	40.00	120.00	80.00
122778	30.00	60.00	30.00	100.00	70.00
13079	20.00	70.00	90.00	120.00	60.00
22779	30.00	130.00	50.00	130.00	90.00
32779	7.30	14.00	7.30	12.00	88.00
43079	22.00	112.00	404.00	102.00	73.00
53079	17.00	103.00	34.00	73.00	56.00
62879	48.00	128.00	88.00	130.00	99.00
73179	9.00	64.00	23.00	83.00	55.00
82979	11.00	60.00	24.00	124.00	46.00
93079	11.00	66.00	21.00	75.00	32.00
103179	5.00	55.00	36.00	88.00	35.00
113079	5.00	18.00	7.00	36.00	15.00
122779	28.00	271.00	159.00	47.00	67.00
13080	32.00	61.00	154.00	68.00	60.00
22880	22.00	51.00	61.00	29.00	37.00
32780	37.00	43.00	46.00	68.00	52.00
42880	43.00	96.00	215.00	202.00	104.00
52880	23.00	45.00	45.00	45.00	45.00
63080	54.00	68.00	27.00	45.00	27.00
73080	300.00	430.00	670.00	840.00	890.00

TABLE A-13. LEAD (µg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	400.00	400.00	400.00	400.00
20175	0.00	500.00	500.00	0.00	0.00
30175	0.00	50.00	50.00	0.00	0.00
40175	0.00	20.00	50.00	50.00	0.00
50175	50.00	50.00	10.00	20.00	0.00
60175	20.00	20.00	60.00	20.00	20.00
70175	20.00	20.00	40.00	20.00	20.00
80175	30.00	20.00	60.00	20.00	20.00
90175	0.00	710.00	990.00	1080.00	670.00
100175	890.00	710.00	1100.00	990.00	760.00
110175	920.00	710.00	1130.00	1010.00	680.00
120175	1600.00	1600.00	500.00	500.00	500.00
10176	0.00	0.00	0.00	0.00	0.00
20176	100.00	100.00	400.00	500.00	100.00
30176	300.00	400.00	400.00	600.00	300.00
40176	300.00	300.00	300.00	800.00	300.00
50176	100.00	200.00	100.00	1100.00	100.00
60176	0.00	0.00	0.00	940.00	0.00
70176	0.00	0.00	280.00	380.00	0.00
80176	30.00	100.00	70.00	470.00	240.00
90176	170.00	100.00	100.00	640.00	200.00
100176	0.00	0.00	0.00	0.00	0.00
110176	0.00	0.00	0.00	0.00	0.00
120176	0.00	0.00	250.00	400.00	250.00
10177	0.00	0.00	250.00	400.00	300.00
20177	0.00	0.00	250.00	300.00	300.00
30177	0.00	0.00	250.00	400.00	250.00
40177	0.00	0.00	300.00	400.00	250.00
50177	0.00	0.00	0.00	0.00	0.00
60177	0.00	0.00	300.00	500.00	0.00
70177	0.00	0.00	0.00	400.00	0.00
80177	0.00	0.00	250.00	450.00	350.00
92077	0.00	0.00	0.00	220.00	220.00

(continued)

TABLE A-13. LEAD (µg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	0.00	0.00	0.00	0.00	0.00
112477	0.00	0.00	0.00	0.00	0.00
122177	0.00	0.00	0.00	0.00	0.00
11678	0.00	0.00	0.00	0.00	0.00
30178	0.00	0.00	0.00	0.00	0.00
32878	0.00	310.00	210.00	210.00	100.00
41778	0.00	0.00	0.00	0.00	0.00
52478	0.00	0.00	0.00	0.00	0.00
63078	0.00	0.00	0.00	0.00	0.00
72678	0.00	0.00	0.00	0.00	0.00
83178	0.00	0.00	0.00	0.00	0.00
92878	1000.00	577.00	1000.00	1000.00	1000.00
103178	340.00	577.00	460.00	1010.00	400.00
112878	40.00	577.00	230.00	820.00	480.00
122778	330.00	290.00	290.00	970.00	530.00
13079	110.00	240.00	31.00	630.00	60.00
22779	180.00	250.00	130.00	810.00	310.00
32779	66.00	260.00	160.00	550.00	340.00
43079	219.00	373.00	237.00	652.00	409.00
53079	167.00	856.00	436.00	641.00	716.00
62879	288.00	591.00	755.00	1050.00	1270.00
73179	135.00	409.00	529.00	716.00	505.00
82979	5.00	108.00	236.00	557.00	265.00
93079	5.00	74.00	163.00	275.00	142.00
103179	5.00	11.00	122.00	522.00	161.00
113079	74.00	79.00	61.00	480.00	239.00
122779	16.00	5.00	44.00	129.00	94.00
13080	64.00	13.00	68.00	151.00	92.00
22880	23.00	87.00	156.00	68.00	310.00
32780	100.00	59.00	51.00	257.00	204.00
42880	75.00	184.00	98.00	191.00	144.00
52880	83.00	83.00	167.00	222.00	167.00
63080	143.00	167.00	143.00	143.00	143.00
73080	400.00	450.00	800.00	800.00	500.00

TABLE A-14. NICKEL (mg/ℓ)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
10175	0.00	0.25	0.25	0.25	0.25
20175	0.00	0.33	0.25	0.00	0.00
30175	0.00	0.25	0.48	0.00	0.00
40175	0.00	0.60	0.59	1.20	0.00
50175	0.12	0.25	0.95	1.21	0.00
60175	0.42	0.41	1.00	1.20	0.41
70175	0.90	0.75	1.10	1.50	0.70
80175	1.20	0.60	1.40	1.80	0.50
90175	0.00	0.34	0.45	1.09	0.62
100175	0.70	0.36	0.54	0.96	0.58
110175	0.70	0.36	0.52	0.98	0.57
120175	0.40	0.40	0.40	0.73	0.40
10176	0.29	0.29	0.29	1.29	0.57
20176	0.48	0.81	1.29	1.81	0.67
30176	0.48	0.67	1.00	1.24	0.48
40176	0.71	0.76	1.62	2.82	0.58
50176	1.00	0.90	2.70	3.00	0.80
60176	0.30	0.50	0.50	2.20	0.89
70176	0.64	0.92	1.10	2.73	0.89
80176	0.20	0.57	0.92	2.11	0.64
90176	0.57	0.47	0.42	2.04	0.57
100176	0.00	0.00	0.00	0.00	0.00
110176	0.00	0.00	0.00	0.00	0.00
120176	0.00	0.60	0.90	3.20	0.60
10177	0.40	0.90	1.10	2.70	1.10
20177	0.20	0.80	1.40	3.10	0.90
30177	0.19	0.62	1.00	1.75	0.60
40177	0.21	0.59	1.06	1.80	0.54
50177	0.00	0.00	0.00	0.00	0.00
60177	0.25	0.60	1.00	1.50	0.50
70177	0.20	0.70	1.20	1.40	0.30
80177	0.29	0.47	0.87	2.17	0.60
92077	0.00	0.00	0.00	0.00	0.00

(continued)

TABLE A-14. NICKEL (mg/ℓ) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
102077	0.35	0.55	0.60	1.25	0.60
112477	0.00	0.45	0.40	1.40	0.40
122177	0.00	0.00	0.00	0.00	0.00
11678	0.13	0.17	0.40	0.70	0.47
30178	0.20	0.27	0.37	0.93	0.47
32878	0.10	0.20	0.50	0.97	0.60
41778	0.08	0.33	0.43	0.83	0.73
52478	0.17	0.25	0.47	0.76	0.52
63078	0.16	0.39	0.43	1.02	0.55
72678	0.23	0.39	0.43	0.82	0.47
83178	0.30	0.60	0.80	1.40	0.70
92878	0.38	0.43	0.00	0.94	0.50
103178	0.23	0.43	0.53	1.39	0.52
112878	0.31	0.43	0.63	1.51	0.60
122778	0.20	0.28	0.40	0.96	0.45
13079	0.18	0.42	0.48	2.06	0.61
22779	0.26	0.57	0.45	1.58	0.65
32779	0.13	0.47	0.29	1.05	0.45
43079	0.10	0.36	0.33	0.79	0.43
53079	0.16	0.47	0.31	0.77	0.50
62879	0.34	0.51	0.44	1.11	0.89
73179	0.15	0.22	0.30	0.63	0.36
82979	0.13	0.13	0.14	0.66	0.29
93079	0.06	0.12	0.11	0.43	0.17
103179	0.12	0.14	0.18	0.60	0.21
113079	0.14	0.09	0.12	0.35	0.26
122779	0.16	0.18	0.18	0.32	0.25
13080	0.13	0.10	0.21	0.33	0.26
22880	0.19	0.14	0.21	0.29	0.17
32780	0.18	0.11	0.13	0.37	0.20
42880	0.21	0.25	0.12	0.25	0.13
52880	0.17	0.24	0.09	0.27	0.07
63080	0.14	0.13	0.08	0.08	0.04
73080	0.16	0.18	0.14	0.24	0.16

APPENDIX B

GAS COMPOSITION DATA

TABLE B-1. METHANE (percent composition)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
30175	0.00	0.00	0.00	0.00	0.00
40175	0.00	0.00	0.00	0.00	0.00
50175	0.00	0.00	0.00	0.00	0.00
60175	0.00	0.00	0.00	0.00	0.00
70175	0.73	0.00	0.40	0.20	0.00
80175	10.70	0.71	10.50	7.30	0.00
90175	24.40	12.80	30.00	16.00	0.00
100175	13.50	21.40	37.10	17.80	0.00
110175	23.70	21.30	22.50	17.50	0.00
120175	25.30	15.60	25.70	15.90	0.00
10176	49.50	6.08	21.80	11.90	0.00
20176	55.60	6.84	10.50	10.50	0.00
30176	22.70	1.28	3.70	1.21	0.00
40176	36.10	2.39	5.42	2.45	0.00
50176	39.00	2.74	5.51	2.19	0.00
60176	46.60	4.76	7.74	5.62	0.00
70176	47.50	6.62	9.50	9.38	0.00
80176	60.20	17.30	30.00	20.20	0.00
90176	48.80	14.50	24.40	16.70	0.00
100176	49.00	14.90	27.70	18.10	0.00
110176	54.50	15.80	28.90	17.00	0.00
30177	36.20	4.91	7.07	3.80	0.00
40177	50.30	0.83	3.28	5.33	0.00
60177	62.30	17.40	16.70	15.00	0.00
70177	19.40	23.20	24.50	20.40	0.00
90177	37.70	16.70	4.90	20.50	0.00
102677	23.20	22.90	19.70	29.20	0.00
112177	21.20	22.40	17.80	29.40	0.00
122177	48.30	11.50	10.20	0.00	0.00
22278	53.80	24.80	15.80	15.20	0.00

(continued)

TABLE B-1. METHANE (percent composition) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
33178	2.41	0.00	13.60	0.00	0.00
50178	57.70	8.73	0.00	0.00	0.00
52678	54.70	16.30	0.00	17.90	0.00
61978	52.60	12.00	0.00	0.00	0.00
71978	55.80	11.70	0.00	0.00	0.00
83178	69.80	24.90	24.90	39.80	0.00
92678	54.90	37.80	33.20	45.70	0.00
102378	56.20	35.30	25.50	42.70	0.00
112178	51.50	32.80	23.30	36.70	0.00
121978	45.20	24.40	18.70	30.40	0.00
12579	49.40	18.30	11.80	29.00	0.90
22279	47.20	23.20	19.10	33.60	0.00
32279	50.80	30.30	0.00	32.10	1.00
42779	51.50	34.10	21.60	33.20	0.00
61179	34.50	3.00	14.30	17.90	0.00
62679	33.40	8.70	29.30	30.60	0.70
73179	50.60	8.10	44.70	45.30	3.50
90779	54.30	0.98	61.30	43.50	0.25
100279	303.00	0.77	36.30	26.90	4.21
110579	42.90	17.80	42.20	37.00	0.00
121779	44.70	27.00	38.70	38.70	0.00
122679	44.10	33.00	39.10	11.80	0.00
12480	46.90	26.60	41.40	38.00	0.00
22580	24.70	29.30	26.10	42.90	0.00
32580	42.60	25.00	23.10	41.30	0.00
42280	45.80	27.30	33.20	40.50	0.00
52280	50.00	32.40	41.90	43.80	0.00
62680	43.00	40.60	44.50	45.10	0.48
72480	43.70	41.60	43.10	45.20	0.00
83180	45.30	44.80	46.30	45.50	1.15

TABLE B-2. CARBON DIOXIDE (percent composition)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
30175	0.00	0.00	0.00	0.00	0.00
40175	0.00	0.00	0.00	0.00	0.00
50175	34.70	24.20	31.40	53.90	29.90
60175	48.20	48.20	58.40	68.10	74.60
70175	48.40	32.20	84.10	89.40	88.70
80175	50.80	33.60	88.00	86.60	89.80
90175	34.00	38.50	67.40	78.30	91.20
100175	18.40	71.20	60.90	75.80	81.10
110175	16.90	71.00	34.70	75.10	86.40
120175	12.10	31.50	28.90	71.60	80.40
10176	20.00	23.80	40.00	65.70	50.70
20176	15.30	29.00	21.60	58.40	23.80
30176	22.10	18.60	24.00	36.70	23.40
40176	32.70	28.20	41.80	54.20	47.90
50176	39.60	37.70	55.00	56.40	42.10
60176	43.80	43.50	61.60	58.70	49.20
70176	49.10	51.30	68.10	64.20	61.40
80176	38.00	48.00	64.90	55.90	64.00
90176	50.50	60.10	70.00	67.70	75.20
100176	50.00	58.70	61.60	63.70	69.10
110176	44.20	51.00	38.90	58.40	62.90
30177	40.80	35.40	32.50	39.50	43.20
40177	35.40	40.50	41.80	41.80	50.50
60177	31.10	37.50	30.90	19.40	25.60
70177	0.80	40.20	45.50	31.00	24.80
90177	59.80	62.40	31.40	61.00	72.30
102677	28.00	56.90	39.90	54.80	58.70
112177	43.70	53.00	48.00	53.20	58.80
122177	40.00	31.90	21.10	39.50	39.00
22278	35.20	38.30	26.50	23.20	16.80

(continued)

TABLE B-2. CARBON DIOXIDE (percent composition) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
33178	6.85	0.19	27.10	0.00	0.00
50178	38.30	26.70	0.00	0.30	0.00
52678	38.20	20.30	0.00	34.10	13.80
61978	41.60	14.70	0.00	0.00	26.90
71978	38.60	14.00	0.00	0.00	25.30
83178	26.10	63.80	45.80	44.60	18.60
92678	40.10	46.80	37.90	46.10	27.40
102378	39.70	42.60	27.70	42.50	20.30
112178	31.20	30.30	24.70	29.50	6.40
121978	42.00	40.50	22.90	51.30	7.00
12579	34.70	24.30	15.30	33.60	18.40
22279	33.70	26.80	25.10	27.50	23.70
32279	38.50	37.90	0.00	38.80	36.60
42779	41.60	36.80	31.50	39.90	9.10
61179	19.50	6.30	16.60	18.30	7.60
62679	36.00	21.00	32.10	39.00	13.90
73179	25.40	4.90	23.20	22.50	6.50
90779	22.30	0.32	17.70	24.10	3.16
100279	31.20	2.70	45.80	54.50	62.10
110579	28.60	17.80	28.10	32.70	11.50
121479	30.20	27.00	29.20	34.60	25.30
122679	33.30	28.60	27.80	5.38	0.00
12480	26.60	22.60	25.00	26.40	28.60
22580	12.90	21.70	13.00	28.60	2.27
32580	29.10	25.00	23.10	29.30	28.40
42280	34.00	26.80	30.50	33.30	32.40
52280	34.60	34.10	28.00	31.40	27.80
62680	33.80	31.60	33.90	37.80	32.40
72480	37.90	34.90	35.40	34.70	40.80
83180	37.40	35.30	33.80	35.90	40.60

TABLE B-3. NITROGEN (percent composition)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
30175	83.30	83.30	85.20	79.50	81.60
40175	80.20	77.80	81.50	0.00	0.00
50175	60.90	68.80	65.80	44.00	63.30
60175	45.50	43.10	33.70	24.70	21.60
70175	49.40	58.90	13.50	10.00	10.70
80175	35.30	55.10	1.10	5.20	7.83
90175	40.00	40.60	2.28	5.39	8.51
100175	62.70	6.99	1.70	6.31	17.60
110175	53.30	7.62	35.60	7.41	13.00
120175	56.80	45.70	37.80	12.60	18.90
10176	28.50	64.40	29.00	21.80	44.60
20176	27.20	60.80	55.60	30.20	69.60
30176	47.90	68.30	60.80	54.30	66.90
40176	30.00	63.20	46.80	42.30	47.90
50176	20.90	56.40	35.60	40.20	54.60
60176	9.42	49.70	28.50	35.00	48.30
70176	3.19	41.50	21.80	26.00	36.70
80176	1.63	34.20	4.97	23.50	35.00
90176	0.73	25.10	5.57	15.40	23.90
100176	0.90	25.90	10.20	17.90	30.90
110176	1.31	32.00	26.80	24.30	35.10
30177	22.50	58.80	59.40	55.60	55.70
40177	14.10	57.40	53.50	52.10	48.70
60177	5.34	42.80	47.60	58.80	71.20
70177	66.60	33.00	28.20	42.50	64.60
90177	2.47	20.60	58.30	17.70	25.40
102677	35.80	19.90	40.50	15.80	38.30
112177	24.30	24.50	33.70	17.40	41.20
122177	10.80	50.90	59.40	49.70	49.20
22278	9.23	35.20	51.90	53.70	71.10

(continued)

TABLE B-3. NITROGEN (percent composition) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
33178	73.70	77.10	53.70	76.80	76.50
50178	4.00	61.20	74.70	75.80	77.90
52678	6.43	60.60	76.30	44.90	72.10
61978	5.12	58.40	76.70	76.90	66.50
71978	5.59	60.50	77.40	77.60	68.50
83178	2.55	9.57	27.10	12.10	66.60
92678	2.20	12.50	25.80	5.30	64.00
102378	2.70	20.50	44.50	12.60	69.50
112178	10.30	29.10	43.30	21.70	70.90
121978	11.50	33.10	46.60	15.70	71.00
12579	11.50	45.20	54.70	30.40	62.90
22279	14.90	40.90	46.00	34.20	68.00
32279	7.90	30.60	77.00	28.10	57.20
42779	6.50	27.90	46.10	26.50	74.10
61179	36.50	75.00	60.30	52.00	75.20
62679	24.70	66.70	34.40	26.20	72.80
73179	19.30	70.00	26.80	26.30	74.10
90779	19.50	78.10	17.80	27.10	79.00
100279	30.60	68.60	14.70	15.50	25.10
110579	24.80	54.90	28.30	29.00	75.50
121479	20.50	40.30	27.20	21.40	64.90
122679	18.60	34.10	27.30	66.10	79.40
12480	22.10	45.20	30.10	28.80	66.00
22580	51.00	43.30	49.60	24.10	79.60
32580	24.30	45.30	48.20	24.60	66.60
42280	17.10	39.70	32.00	21.70	61.10
52280	12.90	29.80	25.30	20.80	68.40
62680	18.40	22.90	17.00	13.90	61.50
72480	14.40	19.00	17.40	16.40	54.60
83180	13.80	16.10	15.80	15.20	53.50

TABLE B-4. OXYGEN (percent composition)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
30175	16.70	16.70	14.80	20.50	18.40
40175	19.80	22.20	18.50	0.00	0.00
50175	4.32	7.00	2.80	2.11	6.81
60175	6.21	8.61	7.90	7.11	3.80
70175	1.45	8.91	2.00	0.40	0.60
80175	3.20	10.60	0.40	0.90	2.37
90175	1.67	8.08	0.30	0.30	0.30
100175	5.31	0.40	0.30	0.10	1.30
110175	6.10	0.00	7.27	0.00	0.60
120175	5.80	7.18	7.56	0.00	0.70
10176	2.00	5.69	9.21	0.60	4.70
20176	1.90	3.42	12.30	0.91	6.59
30176	7.26	11.80	11.50	7.77	9.77
40176	1.25	6.27	5.92	1.02	4.28
50176	0.50	3.15	3.90	1.15	3.39
60176	0.21	2.07	2.17	0.64	2.47
70176	0.22	0.64	0.63	0.43	1.89
80176	0.15	0.60	0.18	0.44	1.03
90176	0.00	0.32	0.00	0.22	0.88
100176	0.10	0.40	0.40	0.40	0.00
110176	0.00	1.24	5.43	0.39	1.96
30177	0.36	0.86	1.08	1.16	1.07
40177	0.24	1.19	1.46	0.73	0.76
60177	1.25	2.19	4.77	6.78	3.19
70177	13.20	3.57	1.82	6.19	10.60
90177	0.00	0.30	5.42	0.81	2.32
102677	13.00	0.28	0.00	0.18	2.95
112177	10.80	0.00	0.54	0.00	0.00
122177	0.83	5.74	9.22	10.90	11.80
22278	1.75	1.69	5.75	7.85	12.10

(continued)

TABLE B-4. OXYGEN (percent composition) (continued)

Date	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
33178	17.10	22.70	5.67	23.20	23.50
50178	0.00	3.41	25.30	23.90	22.10
52678	0.69	2.74	23.70	3.12	14.20
61978	0.67	14.90	23.30	23.10	6.64
71978	0.00	13.80	22.60	22.40	6.25
83178	1.53	1.72	2.16	3.42	14.80
92678	2.90	2.90	3.20	3.00	8.70
102378	1.40	1.60	2.40	2.00	10.30
112178	7.80	7.60	8.70	12.20	22.90
121978	1.30	2.00	11.80	2.60	22.00
12579	4.40	12.20	18.20	7.00	17.80
22279	4.20	9.10	9.80	4.70	8.30
32279	2.80	1.20	23.00	1.10	5.20
42779	0.40	1.20	0.80	0.40	16.80
61179	9.60	15.70	8.90	11.80	17.20
62679	6.00	4.50	4.30	4.20	12.60
73179	4.70	17.00	5.40	5.90	15.90
90779	3.86	20.60	3.23	5.30	17.60
100279	7.86	27.90	3.34	3.12	8.63
110579	3.72	9.52	1.38	1.35	13.00
121479	4.64	5.75	4.91	5.36	9.82
122679	3.92	4.34	5.71	16.70	20.60
12480	4.52	5.58	3.48	6.92	5.43
22580	11.40	5.59	11.30	4.54	18.10
32580	4.09	4.72	5.60	4.65	5.01
42280	3.11	6.19	4.37	4.47	6.55
52280	2.53	3.65	4.81	4.04	3.77
62680	4.76	4.89	4.62	3.25	5.59
72480	4.0_	4.55	4.15	3.80	4.64
83180	3.54	3.82	4.10	3.48	4.76

APPENDIX C

FRANKLIN CELL CLOSURE ACTIVITIES

July 1981

FRANKLIN CELL CLOSURE LOG

Beginning at 10 a.m. on June 30, 1981, the concrete tops of the five test cells at the Franklin, Ohio, test site were removed and loaded onto a tractor-trailer rig for disposal off site. It was observed that the tygon tubing used as the gaskets between the cell walls and lids was not compressed evenly. Some spots on the gaskets appeared deeply dented from stones or irregularities in the lid. Other parts of the gaskets were not compressed at all. This corroborated our belief that the cells were not gas tight.

The cell closure process involved a 7-day effort. On the first day of this effort, the lids were moved from the cells by a crane and loaded onto a semi tractor-trailer. These five lids were hauled from the site for disposal by the construction contractor. During this first day, the pea gravel and clay on the surface of the cells was inspected.

The second and third day of the closure process were spent removing the refuse from the cells. A clamshell on a crane was used to move the refuse from the cells to dump trucks. Two, and sometimes three, dump trucks were used to haul the refuse to a BFI landfill near Hamilton, Ohio. The landfill was operated in compliance with the RCRA Subtitle D provisions. While the refuse was removed from the cells, it was inspected and photographed. A total of 15 dump truck loads of waste was removed.

On the last 4 days of the closure process, a sufficient amount of ground was removed from around the cells to expose the upper portion of the cell walls. The top 5 ft of the concrete cell walls was then broken off and reinforcement rods were sheared off. This material was placed in the remaining cell cavity and the entire area was buried with more than 3 ft of soil. Top soil was spread about the fill, and all equipment was removed to abandon the cleared site.

The following paragraphs present the observed conditions present in the test cells. The five test cells contained municipal refuse in the following conditions: (1) shredded and baled, (2) baled, (3) baled and saturated with water, (4) shredded, and (5) nonprocessed.

Cell 1

In Cell 1 a slight musty odor could be detected. The gravel which formed the top surface of the contents in the cells was loose and fine in texture. A dark outline of the hatch in the lid could be seen on the surface of the gravel.

The moisture distribution system feeder line appeared to be taut probably from settlement of the material. The coal tar epoxy coating on the cell walls appeared to be in good condition. The top surface of pea gravel was 15 in. below the top of the cell wall, and the total thickness of the gravel was about 2 to 4 in.

The clay below the pea gravel of Cell 1 was measured to be 10 to 12 in. thick and had a slight musty odor. Most of this clay was dark in color and moist. There was a transition in color, as the clay was light brown at the top and became gray toward the bottom.

The refuse in Cell 1 appeared to be high in leaves which were dark and black in color. Paper in this cell had not changed in color; it just became wet. The bales were oriented as expected, but the clay along the walls was thick and at some places tapered in horizontally between bales. The silica gravel in the bottom of Cell 1 was cemented and black in color.

Cell 2

Pea gravel in Cell 2 was measured to be 8 1/2 in. below the top of the cell wall. This pea gravel was somewhat cemented. As in Cell 1, a shallow layer of pea gravel was stained black in a square located immediately below the hatch.

Cell 2 clay was dark brown in color near the top and became gray toward the bottom. An organic acid odor was noticeable in the lower levels of gray clay. In this cell the water distribution system was inspected. That system was located in the pea gravel about 1 in. above the clay. Water tubes of the system had numerous spray holes about 3/32 in. in diameter. The holes were unobstructed, and the system appeared to be in generally good condition.

In the refuse, no noticeable food wastes were evident. The waste was moist and had the odor of fresh raw refuse. Evergreen cuttings were still green. As refuse was excavated, a strong organic acid smell became apparent. Cell 2 refuse still appeared whole. It also appeared as though individual pieces of clay had been packed along the walls around the outside of the bales in Cell 2. Observers noted that an entire straw or wood fiber type mat was still visible within the refuse. With the clamshell picking out the refuse, it was difficult to determine whether or not clay had been packed between the bales. The refuse of Cell 2 appeared to get wetter and finer in particle size as the excavation progressed towards the bottom of the cell. The waste of Cell 2 did not appear much different than the waste of the unbaled cells. It did not even appear to be very compacted. The refuse was thoroughly wet, and as excavation moved toward the bottom of the cell, the refuse became wetter. The orientation of the bales was not obvious. However, the clay compacted around the edges was well settled, uniform in texture and color, and moist. The top surface of the silica gravel at the bottom of Cell 2 appeared black in color, but the silica gravel turned white toward the bottom. Near the bottom drain of Cell 2 the silica gravel was black all the way down.

Cell 3

The pea gravel of Cell 3 was cemented for about the top 1 in. of depth, and the top surface of the gravel was 11 in. below the top of the cell wall. This gravel of Cell 3 was reddish brown in color. There was a flaky white deposit on the gravel around the perimeter of its surface. The total depth of gravel was about 2 to 3 inches.

The clay in Cell 3 was a consistent dark brown color. It was wetter than the clay in Cell 2, and it had a definite organic odor. This clay layer was measured to be about 12 in. thick.

It seems that the bales had been centrally placed in the cells. It was observed that there was 15 to 18 in. of clay around the edges of the bales. The top layer of the refuse appeared moist, like garbage sitting out on a rainy day. When the bales were broken open, the interiors appeared to be somewhat dry. However, when actually feeling the material, it felt moist to the touch; but no free moisture could be pressed out. Decomposition did not seem to have progressed any further than in Test Cells 4 or 5. Also, there visually seemed to be less decomposition of the waste in the middle portion of the bales, but such determination was difficult to make because the bales were broken up pretty badly by the clamshell. Bales did seem to have expanded with the moisture. There didn't seem to be any interstices between the clay and the garbage. Of course, because of the clamshell working, it was difficult to tell where the clay left off and the garbage began. There seemed to be more plastic bags in Cell 3 waste than in the waste from Oakwood which was in Cell 5. There were 5 in. of silica gravel in the bottom of the cell which appeared white and dry with no cementation.

Cell 4

The pea gravel of Cell 4 was notably more coarse than the pea gravel of Cell 2 or 3. Except for the dark square in the center, this pea gravel was light in color. The entire top surface was cemented for about a 1-in. depth. This 10-in. thick layer of pea gravel had a top surface located 14 in. below the top of the cell. The most noticeable feature of the pea gravel in Cell 4 was the crimson red chunk near the center of the surface. This section was red and cemented to about a 1-in. depth. Near the center of Cell 4 the pea gravel was notably deeper, and the lower surface of this gravel was wet.

This cell had about 14 in. of clay. The clay had a light brown color, no noticeable odor, and was moist. In the top few feet of refuse there was a tendency for the material closer to the walls to be very moist. The material in the center appeared dry as if water was somehow infiltrating down the sides and into the wastes. Corresponding to this moisture there was evidence of decomposition (some blackness in the wastes near the edges), but the material in the center appeared to have undergone almost no decomposition. The material in the center was slightly damp to the touch. The material at the edges was moist enough to express water when you squeezed the material between your fingers.

At about 5 to 6 ft down into the refuse in Cell 4 the material was still higher in moisture around the edges than it was in the middle. It would seem that any anomalies that may have occurred in the moisture retention curves in prior reports were probably due to the fact that the refuse was not uniformly wetted, and moisture was leaching to the bottom at a higher rate than it was infiltrating into the middle of the refuse.

A portion of the silica gravel in the bottom was cemented and black. Other portions were still white and loose.

Cell 5

Cell 5 has pea gravel about 8 in. in depth with a top surface 19 in. below the top of the cell wall. This pea gravel was white in color and not cemented. There was a dark square in the center like in the other cells.

The clay in Cell 5 was drier than the clay of the other cells. The total depth of the clay appeared to be about 14 in., but the depth was not uniform. The top 8 in. was brown in color, and the lower 5 to 6 in. was gray. The gray clay had an organic odor.

When the refuse of Cell 5 was uncovered, newspapers were still readable; clothing, both natural and artificial fibers, appeared to have undergone minimal degradation; uncoated cardboard seemed to have degraded the most, yet it still held its structure. The material appeared to have decayed about as much as if it had been set outside in the rain for a couple of weeks. On the whole, the refuse appeared moist with a very minor amount of degradation. Plastics, of course, appeared to have undergone no degradation. Seven years under moist anaerobic conditions seemed to have caused little if any degradation of the wastes placed in Cell 5. All the plastic garbage bags appeared to have been broken. Apparently, the breakage and compaction process at the time of installation was effective. There does not seem to have been any significant amount of protection of the organic materials from having been trapped in plastic garbage bags. At the 4-to 6-ft level there seemed to be a very slight amount of the totally black decomposed material indicative that the kitchen wastes, etc., might have decayed to completion. Food waste seemed to be the only material that suffered a significant amount of deterioration. The newspapers were still quite legible. Some of the newspapers had yellowed while others were still fairly white and clean but damp. There was probably about a 30 to 40 percent overall moisture content in the waste material in this cell. Silica gravel in the bottom of test Cell 5 was loose and white throughout its 1-ft depth.

Summary

In general, the nature and extent of waste degradation was very similar from cell to cell. Food wastes were almost completely degraded. Plastics and artificial fibers were very minimally degraded. Of the natural (as opposed to man-made) organics, the cellulosic materials such as paper, wood, and some natural fibers appeared to have undergone almost no degradation in any of the cells.